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RAFINESQUE AND THE TAXONOMY OF INDIANA VASCULAR PLANTS

By RAY C. FRIESNER, Butler University

In a previous paper (1) a general summarizing treatment of the relation of Rafinesque's work to the taxonomy of Indiana vascular plants was given. The object of the present paper is to cite in a more detailed manner the bases for the earlier statements. The present data are based upon Merrill's Index Rafinesquianus (2) and a number of Rafinesque's own publications (which will be cited individually as use is made of them).

Rafinesque proposed 22 names based upon material collected in Indiana. Of these 22 names only one, viz. *Oenothera pilosella* Raf. occurs as a valid name in Gray's Manual 8 ed. The identity of 6 others is unknown, leaving 15 as invalid names. These, together with present-day identity and places of publication, are given in table I.

Of the 1210 names proposed by Rafinesque to 654 taxa which presently occur in Indiana, 33 are to be found as valid names in Gray's Man. 8 ed. These names are: *Potamogeton diversifolius* Raf., *P. epihydrus* Raf., *P. foliosus* Raf., *Alisma subcordatum* Raf., *Tradescantia ohioensis* Raf., *Clintonia borealis* (Ait.) Raf., *Trillium flexipes* Raf., *Sisyrinchium albidum* Raf., *Isotria verticillata* (Willd.) Raf., *Spiranthes lacera* Raf., *S. tuberosa* Raf., *Corallorhiza maculata* Raf., *Tovaria virginiana* Raf., *Cerastium nutans* Raf., *Ranunculus flabellaris* Raf., *Polanisia graveolens* Raf., *Parnassia glauca* Raf., *Rubus pubescens* Raf., *Acalypha rhomboidea* Raf., *Euphorbia supina* Raf., *E. vermiculata* Raf., *Opuntia humifusa* Raf., *Epilobium leptophyllum* Raf., *Oenothera pilosella* Raf., *Cornus obliqua* Raf., *Samolus parviflorus* Raf., *Asclepias viridiflora* Raf., *Lycopus amplexans* Raf., *Chelone glabra* var. *elatior* (L.) Raf., *Cephalanthus occidentalis* var. *pubescens* Raf., *Viburnum rufidulum* Raf., *Solidago sphacelata* Raf.,

NOTE: This is publication 275 of the Botanical Laboratory of Butler University. It is the last paper written by the late Dr. Ray C. Friesner. It was presented before the History of Science section at the annual meeting of the Indiana Academy of Science, Valparaiso, Indiana, October 17, 1952. Dr. Friesner died on December 1, 1952.

S. rupestris Raf., *Helianthus hirsutus* Raf., and *Erechtites hieracifolia* (L.) Raf.

Of the 654 species and varieties of plants occurring in Indiana and to which Rafinesque gave names, 285 were given two or more names each by him. One species, viz. *Prunella vulgaris* was given a total of 18 different names; one, viz. *Brauneria purpurea* was given 16 different binomials; and two, viz. *Amphicarpa bracteata* and *Hamamelis virginiana* were given 15 names each. Only slightly more than one-half of the entities which occur in Indiana and to which he gave names received a single name from his pen. The complete picture of the situation from this standpoint is shown in table II. Only 2.73% of the total Rafinesquian names proposed for plant taxa which occur in Indiana are currently in use. The over-all situation may be seen from the following summary.

SUMMARY

1. Indiana species and varieties to which Rafinesque gave names	654
2. Total number of names Rafinesque gave to Indiana taxonomic entities	1210
3. Rafinesquian names now in use for Indiana plants	33
4. Percentage of total Rafinesquian names proposed for Indiana plants that are now in use	2.73%
5. Rafinesquian names based upon specimens collected in Indiana	22
a. Names now invalid	15
b. Identity unknown	6
c. Names known to be valid	1

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11. ———. *Am. Monthly Mag. Crit. Rev.* 4:40. 1818.

TABLE I

Rafinesquian names based upon plants collected in Indiana.

Rafinesquian name	Place and Date of Publication	Present-day Identity ¹
1. <i>Onoclea dentata</i>	Herb. Raf. 63. 1833 (3)	Unknown
2. <i>Tradescantia rupestris</i>	Atl. Jour. 1:150. 1832 (4). "Cliffs and rocks of the Wabash." New Fl. N. Amer. 2:86. 1836. (5) "Cliffs of Ohio and Wabash Rivers."	<i>T. virginiana</i> L.
3. <i>Rosa acuminata</i>	Ann. Gen. Sci. Phys. 5:216. 1820 (6). "Indiana?" (2)	Unknown
4. <i>R. dasistema</i>	Ibid. 5:219. 1820. "Ohio, Indiana." (2) Rydb. N. Amer. Fl. 22:497. 1918 (7). "West Virginia to Indiana and Missouri."	
5. <i>R. globosa</i>	Ann. Gen. Sci. Phys. 5:215. 1820. "Indiana, Illinois?" (2)	<i>R. palustris</i> Marsh.
6. <i>R. pratensis</i>	Ann. Gen. Sci. Phys. 5:215. 1820. "Indiana, Illinois, Kentucky." (2)	<i>R. carolina</i> L.
7. <i>Sorbus riparia</i>	New Fl. N. Amer. 3:15. 1836 (1838) "Margins of Rivers the Missouri Upper Miss., lower Ohio, Wabash, Illinois."	<i>S. americana</i> Marsh or <i>S. decora</i> Schneider
8. <i>Spiraea ciliata</i>	New Fl. N. Amer. 3:66. 1836 (1838) "From the River Wabash, to Carolina."	<i>S. alba</i> Du Roi
9. <i>Amorpha tomentosa</i>	Aut. Bot. 81. 1841. (8) "On Wabash and West Kentucky."	<i>A. canescens</i> Pursh
10. <i>Oenothera pilosella</i>	Herb. Raf. 62. 1833. Ann. Nat. Ann. Synop. 15. 1820. (9) First Cat. Bot. Gard. Transylv. Univ. 15. 1824. (10) "Indiana." (2)	<i>Oe. pilosella</i> Raf.
11. <i>Dodecatheon angustifolium</i>	Am. Monthly Mag. Crit. Rev. 4:40. 1818. "Indiana and Kentucky." (2)	Unknown
12. <i>Forestiera cuneifolia</i>	New Fl. N. Amer. 3:91. 1836 (1838) "On the banks of the Wabash."	<i>F. acuminata</i> (Mx.) Poir.
13. <i>Cuscuta aphylla</i>	Am. Monthly Mag. Crit. Rev. 4:40. 1818. "Indiana, Kentucky, Illinois?" (2)	<i>C. glomerata</i> Choisy
14. <i>C. paradoxa</i>	Ann. Nat. Ann. Synop. 13. 1820. "Indiana, Illinois, Kentucky?"	<i>C. glomerata</i> Choisy
15. <i>Blephilia</i>	New Fl. N. Amer. 4:96. 1836 (1838) "Kentucky, Indiana, Illinois, discov. 1818."	<i>B. hirsuta</i> (Pursh) Benth

TABLE I—(Continued)

Rafinesquian names based upon plants collected in Indiana.

Rafinesquian name	Place and Date of Publication	Present-day Identity ¹
16. <i>Scutellaria villosa</i>	Atl. Jour. 1:17. 1832. "Indiana and Kentucky woods."	Unknown
17. <i>Helenium flexuosum</i>	New Fl. N. Amer. 4:81. 1836 (1838) "Found on R. Wabash."	<i>H. nudiflorum</i> Nutt.
18. <i>Helichroa crocea</i>	Atl. Jour. 1:150. 1832. "Glades of Wabash."	<i>Brauneria pallida</i> (L.) Britt.
19. <i>H. fuscata</i>	Atl. Jour. 1:150. 1832. "Glades of Wabash."	<i>B. pallida</i>
20. <i>Heliochroa crocea</i>	Herb. Raf. 32. 1833. "Indiana." (2)	<i>B. pallida</i>
21. <i>H. fuscata</i>	Herb. Raf. 31? 1833. "Indiana." (2)	<i>B. pallida</i>
22. <i>Lophactis uniflora</i>	Atl. Jour. 1:152. 1832. "White R. Indiana." "Noticed in 1818 . . . on the Wabash."	<i>Coreopsis</i> sp.?

¹Identities are taken from Merrill (2).

TABLE II

Number of Rafinesquian Names Given to Species and Varieties Occurring in Indiana.

No. of Names per Species	No. of Species	Total No. of Names
1	369	369
2	113	226
3	52	156
4	30	120
5	17	85
6	9	54
7	5	35
8	1	8
9	4	36
10	1	10
11	2	22
12	1	12
13	1	13
15	2	30
16	1	16
18	1	18
	654	1210

THE CHARACEAE OF INDIANA

By FAY KENOYER DAILY

This is the third in a proposed series of papers intended to organize the material pertaining to the occurrence and distribution of the Characeae of Indiana and to present a taxonomic treatment of the group.

In the first paper (Daily, 7) only collections which had not been previously reported were cited. In the second paper (Daily, 10) a genus not previously found in the state, *Tolypella prolifera* Leonh., was given. For the present study, an attempt was made to obtain both reported and unreported specimens extant, and to make further collections. Typic or co-typic specimens were studied whenever possible.

The attempt to obtain previously reported material for study was not so successful as far as those papers citing only generic names were concerned. The majority of such reports were apparently incidental to other studies and probably specimens were not prepared. Generic reports have been published in papers by: J. D. Black (3); Severance Burrage (4); H. Walton Clark (5); Willis DeRyke (11); C. H. Eigenmann (12); B. W. Evermann and H. Walton Clark (13, 14, 15); Shelby D. Gerking (18); L. N. Johnson (21); L. J. King (22); Philip H. Kirsch (23); W. M. Mills (24); D. M. Morris and A. Hale (25); D. M. Mottier (26); C. M. Palmer (27, 29); C. E. Parks (30); W. E. Ricker (32, 33); Will Scott, Ralph Hile and H. T. Spieth (36); J. T. Scovell (37, 38, 39); B. H. Smith (40); and Donald E. Wohlschlag (41). When any of the specimens were found, they have been cited under the specific heading to which they belong in the systematic account, except when the condition of the specimen made specific determination impossible.

Greater success was realized in obtaining collections which are the bases of reports in which specific names were given. The study in which the largest number of specimens was treated is the work by Evermann and Clark (15) on Lake Maxinkuckee and vicinity. Although it was not possible except in a few instances to state definitely that collections found were the bases of the published species because exact collection data were not always given, it is probable that the

TABLE I
The Species of the Characeae from Indiana Arranged Chronologically by
Author and According to their Disposition in the Present Study

Schneck (35), 1876	Robinson (34), 1906	Evermann & Clark (15), 1920	Smith (40), 1932	Palmer (28), 1934	Daily (7), 1945	Daily (10), 1950	Present Study
Chara polyphylla?	Chara longifolia?	Chara foliolosa			Chara gymnopus		Chara zeylanica
		C. fragilis	Chara fragilis?	C. fragilis	C. fragilis		C. globularis
		C. contraria	C. contraria?	C. fragilis	C. contraria		C. contraria
		C. vulgaris & C. foetida?			C. foetida		C. vulgaris
		C. gymnopitys?	C. delicatula		C. gymnopitys		C. keukensis
		C. subvernucosa			C. verrucosa		C. delicatula
		Nitella tenuissima	Nitella tenuissima				Nitella tenuissima
		N. batrachosperma					N. tenuissima
		N. mucronata					N. megacarpa
		N. monodactyla?					
					Nitella flexilis		N. flexilis
					N. opaca		N. opaca
					C. aspera		C. aspera
					C. Brittonii		C. Brittonii
					C. coronata		C. Braunii
					C. hydropitys		C. hydropitys
					C. sejuncta		C. sejuncta
						Tolypella prolifera	Tolypella prolifera
						N. acuminata	N. acuminata
						C. excelsa	C. excelsa
						C. Kieneri	C. Kieneri

material supplied constituted the complete collection extant. J. T. Scovell collected some specimens for this study and included among them might have been specimens reported by him (37) earlier by genus name only. Most of the specimens for the Lake Maxinkuckee study were lodged at the United States National Museum. A few were located at the Chicago Natural History Museum, and all were kindly loaned for study. They were particularly interesting because the largest part of the dried material had been submitted to Dr. C. B. Robinson for identification and the alcoholic collection had been sent to Dr. George T. Moore.

Dr. C. M. Palmer, who wrote on the algae found in Steuben County (28), kindly supplied specimens of the Characeae from that county. The check lists of the algae of Indiana by Palmer (27, 29) covering the period from 1875 to 1928 were very helpful in bibliographic work.

As far the author knows, ten papers previous to the present series reported specimens of the Characeae from Indiana by specific name, only five of which were original reports. In Table I can be seen the disposition in the present paper of specimens reported from the state by specific name. Only original reports are included. Subspecies, varieties and forms are not considered in this table; so for a more detailed analysis see the "Systematic Account." Following a line across to "Present Study," one will find whether or not a previously published name has been excluded, changed, substantiated by further collection, and under what name to find it classified in the "Systematic Section" of this study. If a name does not appear in "Present Study," the previous report on that line was based upon a specimen which has not been seen and no other specimen of that species has been found in the state; so it is not included here. Specimens which were not seen are indicated in the table by a question mark. All reports on the same line are considered by the author to belong to the same species listed in "Present Study," except those specimens which were not seen must remain questionable. If the names in previous reports are different from those in "Present Study," they have either been reclassified if specimens were seen, or another name has been used because of its priority. As one progresses across the table from left to right, species not previously reported for the state may be seen below the lowest species listed in preceding columns. In some cases, a new name may appear in a column not found in previous columns,

but must be placed opposite a former report because of reclassification or because of the synonymy of the names.

Fourteen species had been listed for the state before the present series of papers. That number has been reduced to eight by reclassification, reduction to synonymy and exclusion because specimens were not seen. With the addition of eleven more species found in collections formerly unreported or reported by generic name only, the present study recognizes nineteen species collected in Indiana.

About 360 collections made by the author and 135 by others making a total of about 495 collections are treated in this study. Only twenty-seven specimens have been obtained so far to represent the bases for previous reports.

Plate I gives the distribution of the Characeae in Indiana. Each of the first nineteen maps gives the distribution of a single species in the state by county. The last map shows all of the species plotted by county. A dot marks the occurrence of a species in the county where it is placed.

The citation of collections of the Characeae identified to species had appeared in the literature for only four counties before the present series of papers (Gibson, Marshall, Steuben, and Cass). Now fifty-six out of ninety-two counties in the state have collection records. Thirty-six counties remain from which no substantiated records have been obtained.

A large percent of the collections came from the northern part of the state from the lakes of glacial origin, some of which have developed boggy areas. The Characeae abound in this region making it particularly attractive to the collector of this group. Collections from the rest of the state are more often from man-made rather than natural habitats. These include gravel pits, quarry pits, strip mine ponds, drainage ditches, artificial lakes and ponds often connected with fish propagation activities. The natural habitats from the central and southern part of the state include a few lakes such as the old oxbows of the lower Wabash River, bogs, obstructed sink holes, spring-fed ponds and small lakes, and usually the more sluggish areas of streams.

In the citation of specimens, the following abbreviations are used to indicate the herbaria in which they may be found: BU, Butler University; CM, Chicago Natural History Museum; USM, United States National Museum; HafR, Horn af Rantzien at the Natur-

historiska Riksmuseet, Sweden; GOA, G. O. Allen of Godalming, Surrey, England; DU, DePauw University; EC, Earlham College.

When it is stated that a species occurs *with* another in a collection, it is filed under the latter name in the herbarium.

Specimens having more than one collector listed with the name of the author last are part of the personal herbarium of the author.

SYSTEMATIC ACCOUNT

KEY TO THE CHARACEAE OF INDIANA

- Coronula composed of two superimposed tiers of five cells each
Antheridia and oogonia lateral at the nodes of the
branchlet, oospore terete.....I. TOLYPELLA
Coronula persistent, sterile branchlets not divided,
oospore ca. 368 μ long.....1. *T. prolifera*
Antheridia produced terminally on the upper end of a ray
where branchlet furcates, oospore laterally flattened.....
.....II. NITELLA
Ultimate rays one-celled
Dioecious; branchlets simple, once furcate.....
.....2. *N. opaca*
Monoecious
Branchlets simple, once furcate
Ultimate rays acute.....3. *N. flexilis*
Ultimate rays acuminate.....4. *N. acuminata*
Ultimate rays usually two-celled, not much abbreviated
with the ultimate cell short, conical.....5. *N. tenuissima*
Ultimate rays three-four-celled, unequal in size, some
quite abbreviated, forming a two-four cuspidate crown;
upper branchlets often with four furcations..6. *N. megacarpa*
Coronula composed of five cells in one tier.....III. CHARA
Stem not corticated
One series of stipulodes in a circle around stem at
the base of a branchlet whorl.....7. *C. Braunii*
Two series of stipulodes in a circle around stem at
the base of a branchlet whorl.....8. *C. Brittonii*
Stem corticated
Monoecious
One series of stipulodes in a circle around stem
at the base of a branchlet whorl

- Branchlets entirely ecorticate.....9. *C. keukensis*
 Branchlets (at least some of them) corticate.....
10. *C. hydropitys*
 Two series of stipulodes in a circle around stem
 at the base of a branchlet whorl
 Stem falsely diplostichous (usually only one
 secondary cell between primaries, but occasionally
 two making the cortex triplostichous in some places,
 spines usually single).....11. *C. excelsa*
 Stem falsely diplostichous and occasionally falsely
 haplostichous, spine cells usually single but
 occasionally two-together.....12. *C. Kieneri*
 Stem diplostichous
 Primary cortical cells of stem prominent.....
13. *C. contraria*
 Secondary cortical cells of stem prominent...
14. *C. vulgaris*
 Stem triplostichous
 Cells of stem cortex about equal in size
 Branchlet cortication diplostichous
 (cortical cells twice the number of bract
 cells), branchlets with usually some corticated
 internodes, especially the lowest.....
15. *C. globularis*
 Branchlet cortication triplostichous,
 lowest internode always ecorticate
 (sometimes all ecorticate)
 Antheridia and oogonia borne at the same
 branchlet node.....16. *C. zeylanica*
 Antheridia and oogonia borne at
 different nodes.....17. *C. sejuncta*
 Primary cells of stem cortex prominent.....
18. *C. delicatula*
 Dioecious.....19. *C. aspera*

I. TOLYPELLA A. Br. emend Leonh.

1. TOLYPELLA PROLIFERA Leonh. Lotos 13, p. 57. 1863.

For general description and illustrations see Daily (8 and 10).
 The size range of oospores in Indiana material is 300-375 μ long,
 275-315 μ broad.

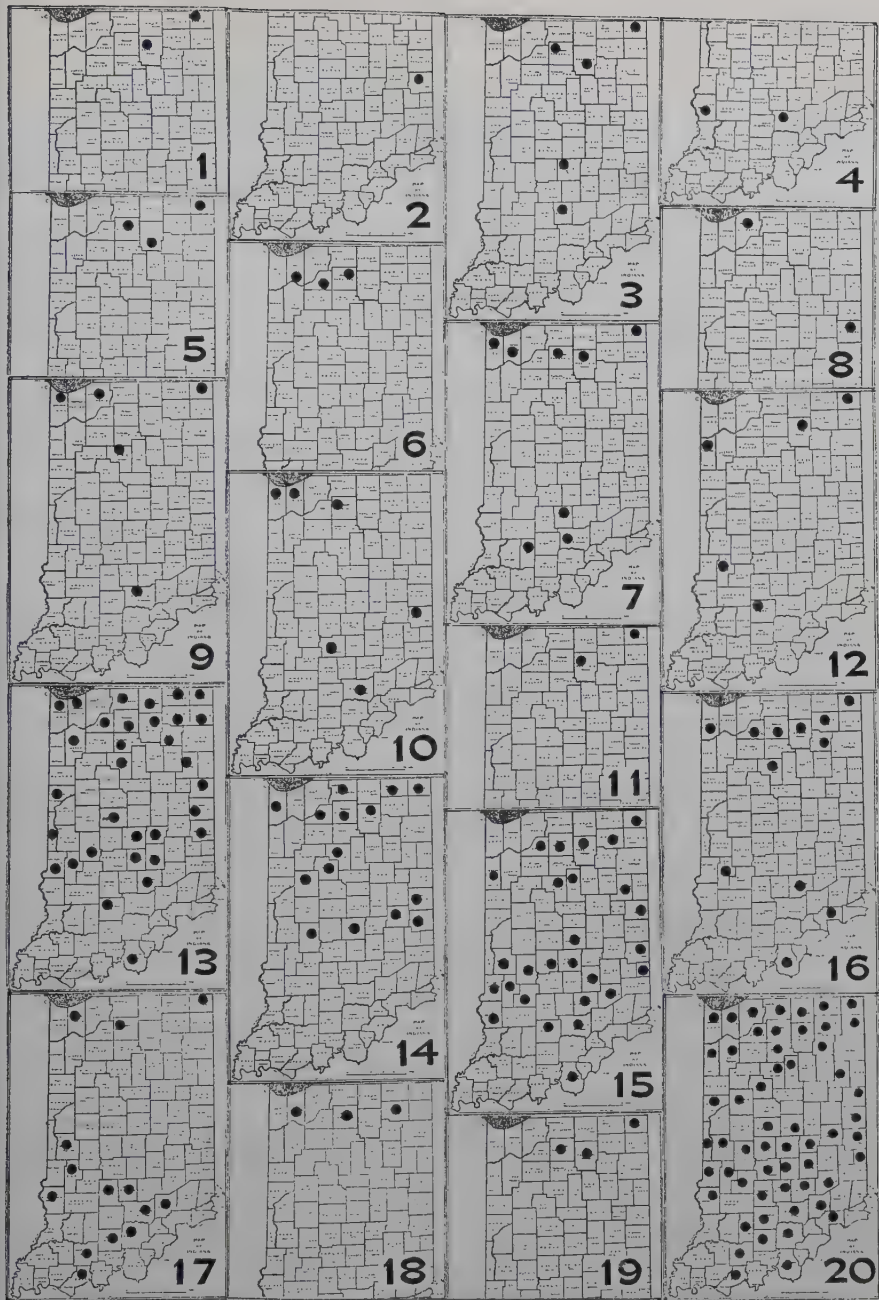


Plate I. Distribution of the Characeae of Indiana. 1. *Tolypella prolifera* Leonh. 2. *Nitella opaca* (Ag. ex Bruz.) Ag. 3. *Nitella flexilis* (L. pro parte) Ag. 4. *Nitella acuminata* A. Br. ex Wall. 5. *Nitella tenuissima* (Desv.) Kütz. 6. *Nitella megacarpa* T. F. Allen. 7. *Chara Braunii* Gmel. 8. *Chara Brittonii* T. F. Allen ex Robinson. 9. *Chara keukensis* (T. F. Allen) Robinson. 10. *Chara hydropitys* Reich. in Mössler. 11. *Chara excelsa* T. F. Allen. 12. *Chara Kieneri* Daily. 13. *Chara contraria* A. Br. ex Kütz. 14. *Chara zeylanica* Willd. 15. *Chara globularis* Thuill. 16. *Chara vulgaris* Vaill. ex L. 17. *Chara sejuncta* A. Br. 18. *Chara delicatula* Ag. 19. *Chara aspera* Willd. 20. All species.

Specimens seen: KOSCIUSKO COUNTY: Dredged collection, Syracuse Lake, Syracuse City Park Pier, *W. A. & F. K. Daily* 212 with *C. contraria*, July 23, 1950 (CM, HafR, BU). STEUBEN COUNTY: Dredged collection, Circle Park, Hamilton Lake, *W. A. & F. K. Daily* 288B with *C. Kieneri* (GOA, BU), 288C (CM, HafR, BU), June 17, 1951; dredged collection, Cold Springs Resort, Hamilton Lake, *W. A. & F. K. Daily* 289B, June 17, 1951 (CM, HafR, GOA, BU); dredged collection, east of bridge over canal between middle basin of Lake James and Jimerson Lake on the Lake James side, *W. A. & F. K. Daily* 318, June 19, 1951 (GOA, BU).

For further citation of specimens see Daily (10). In this study, a collection was reported from Steuben County.

II. NITELLA Ag. emend. A. Br.

2. NITELLA OPACA (Ag. ex Bruz.) Ag. Syst. Alg., p. 124. 1824.

For a general description and illustrations see Daily (6). A more nearly exact description of some characteristics found in Indiana plants is: ripe oospores chestnut brown, ca. 420 μ long, ca. 367 μ broad, with 7 ridges; outer oospore membrane red brown, translucent, with warty protuberances; antheridia as large as 682 μ in diameter.

Apparently only one collection of this species in Indiana has been made so far. This was found in Wayne County by L. J. King. For the complete specimen citation see Daily (7). This report for Indiana was also cited by Wood (42).

3. NITELLA FLEXILIS (L. pro parte) Ag. Syst. Alg., p. 124. 1824.

Habit spreading, fairly stout; monoecious; fertile and sterile branchlets usually 6-8 at a node, similar except in capitate forms in which fertile branchlets may be more or less condensed; branchlets with one furcation at which usually 2 and sometimes either 1 or 3 ultimate rays may be produced; oogonia 1-3 at a node; oospores red-brown to black, 420-580 μ in length, 400-495 μ in width with ca. 7 prominent ridges; outer oospore membrane smooth or scabrous with wart-like protuberances; antheridia ca. 504-630 μ in diameter.

NITELLA FLEXILIS (L. pro parte) Ag. var. *flexilis* Plate II-A

That part of the taxon containing the type specimen for the species belongs here. The type specimen has not been seen by the



Plate II. A. *Nitella flexilis* (L. pro parte) Ag. var. *flexilis*. 1. Part of branchlet. 2. Coronula. 3. Oospore. 4. Portion of plant, natural size. B. *Nitella flexilis* var. *subcapitata* (A. Br.) Crepin. 1. Part of branchlet. 2. Coronula. 3. Oospore. 4. Portion of plant, natural size. C. *Nitella megacarpa* T. F. Allen. 1. Branchlet. 2. Coronula. 3. Tips of ultimate rays. 4. Oospore. 5. Outer colored membrane of oospore (a small portion). 6. Tip of the plant, natural size. D. *Chara Brittonii* T. F. Allen ex Robinson. 1. Plant, natural size. 2. Oospore. 3. Branchlet. 4. Oogonium. 5. Base of branchlet whorl. E. *Chara keukenensis* (T. F. Allen) Robinson. 1. Portion of plant, natural size. 2. Base of branchlet whorl and one branchlet in detail. 3. Oospore. 4. Stem cortex (portion). 5. Oogonium. F. *Chara hydrophytes* var. *septentrionalis* Nordst. 1. Portion of stem cortex. 2. Oogonium. 3. Base of branchlet whorl and one branchlet in detail. 4. Portion of plant. 5. Oospore. G. *Chara excelsa* T. F. Allen. 1. Oospore. 2. Portion of cortex. 3. Base of a branchlet. 4. Oogonium. 5. Portion of plant, natural size.

author, but those plants having branchlets of a whorl similar in size, fertile branchlets not reduced to form a head, and branchlets once-furcate and bearing usually 2 or 3 ultimate rays are usually considered typical of the species.

Specimens seen: BROWN COUNTY: Dredged collection, Jimmy Strahl Lake, Brown County State Park, *John H. Wallace, W. A. & F. K. Daily 131*, Apr. 20, 1947 (CM, HafR, BU) ; dredged collection, Jimmy Strahl Lake, Brown County State Park, *W. A. & F. K. Daily 132*, Apr. 26, 1947 (CM, HafR, BU) ; dredged collection, north side of Ogle Lake, Brown County State Park, *John H. Wallace, Ann Jensen, W. A. & F. K. Daily 134* (BU), *135* (CM, BU), Apr. 27, 1947 ; dredged collection, Yellowood Lake, 5 mi. southwest of Nashville, *John H. Wallace, Ann Jensen, W. A. & F. K. Daily 136*, Apr. 27, 1947 (CM, HafR, BU) ; dredged collection, Jimmy Strahl Lake, Brown County State Park, *Mary Fritsche, W. A. & F. K. Daily 170*, Sept. 19, 1947 (BU). STEUBEN COUNTY: Dredged collection, Silver Lake, ca. 3 mi. west of Angola on U. S. Rd. 20, *W. A. & F. K. Daily 333*, June 20, 1951 (CM, HafR, GOA, BU).

See Daily (7) for further citation of specimens. In that study, specimens were reported from Marion and Steuben Counties. This report was also cited by Wood (42).

NITELLA FLEXILIS var. SUBCAPITATA (A.Br.) Francois Crepin. *Bul. Bot. Soc. Belg.* 2: 129. 1863. (Auct. non *Nitella flexilis* var. *nidifica* Wall.)

Plate II-B

Differing from the type in having fertile branchlets somewhat reduced in size and more or less unequal in length produced in more or less condensed clusters particularly at the top of the plant. Ultimate rays are frequently produced singly at a furcation rather than in the typical numbers of 2 or 3.

The author agrees with Groves and Bullock-Webster (19, Vol. 2, p. 107) that *Nitella flexilis* var. *subcapitata* is distinct from *Nitella flexilis* var. *nidifica*. The latter differs chiefly in having a more extreme reduction of the size of fertile whorls. There are other differentiating characteristics.

This variety has not been previously reported for the state. It is possible, however, that the specimens from Lake Maxinkuckee, Marshall County, reported by Evermann and Clark (15) and cited

by Palmer (27) under the name, *Nitella monodactyla* A. Br., belonged in this group. Later in the Evermann and Clark work, the collections are again discussed under the heading, *Nitella* sp., and it is revealed that the material examined by Dr. C. B. Robinson was sterile. It may have been an error that the earlier heading of *N. monodactyla* was included as Dr. Robinson did not commit himself definitely to this diagnosis because of the sterility of the material. Apparently none of the material is preserved. However, more recent collections from the Outlet of Lake Maxinkuckee possibly may be the same if the *Nitella* were maintained or reoccurred in that location during the intervening years. Since this material is fertile, it is referable to *N. flexilis* var. *subcapitata* which might possibly be confused with *N. monodactyla* if sterile. Mr. Russell Fisher of Culver, Indiana, recalled the collection of *Nitella* in the Outlet during the Lake Maxinkuckee Survey by Evermann and Clark for he accompanied the collectors then, and made possible the present collections there.

Specimens seen: KOSCIUSKO COUNTY: Dredged collection, behind Johnson's Hotel Annex, Lake Wawasee, *W. A. & F. K. Daily* 202 (CM, BU), 206 (BU), July 23, 1950. MARION COUNTY: Near water works, Fall Creek at Keystone Ave., Indianapolis, *C. M. Palmer*, May, 1931 (BU). MARSHALL COUNTY: Mud bottom, water ca. knee deep, water plants dense, Outlet, Lake Maxinkuckee, *Russell Fisher*, *W. A. & F. K. Daily* 119 (CM, HafR, BU), 120 (BU), July 5, 1946; shallow water, mud bottom, Outlet, Lake Maxinkuckee, *Russell Fisher*, July 8, 1946.

4. *NITELLA ACUMINATA* A. Br. ex Wall. Försök till en systematisk uppställning af vaxtfamiljen Characeae, p. 263. Stockholm. 1853.

Habit spreading and often diffusely branched; plants usually ca. 20-25 cm. high; stem ca. 1000 μ in diameter, sterile branchlets slightly smaller; monoecious; sterile whorls slightly to far exceeding the fertile whorls (i.e. sterile whorls lax, long; fertile whorls more or less condensed, borne on a peduncle of varying length located in the axils of the sterile whorls); branchlets 6-8 at a node, similar, once-divided into 2-4 one-celled terminal rays which gradually taper to a point; fruiting bodies not enveloped in jelly; oogonia 1-3 at a node; coronulae short, persistent; oospores usually with 7 ridges, spherical, reddish-brown; membrane light brown, translucent, with raised elevations or granular (granules may be arranged reticulately in mature oospores, scattered or not present in immature oospores); antheridia ca. 320 μ in diameter.

NITELLA ACUMINATA var. SUBGLOMERATA A. Br. Abh. Kön. Akad. Wiss. Berlin, p. 36. (1882) 1883.

Present collections of this species in Indiana apparently belong to this variety.

See *Nitella subglomerata* (as synonym) in Daily (6) for general description and illustrations. In Indiana specimens, the sterile branchlets are not greatly overtopping the fertile ones, sterile branchlets are up to ca. 4.5 cm. long with primary rays ca. $\frac{3}{4}$ the total length of the branchlet, fertile whorls are borne on a peduncle and consist of branchlets ca. 3.5 mm. long with primary rays ca. $\frac{1}{2}$ - $\frac{2}{3}$ the total length of the branchlet. Oospores are 300-315 μ long, 255-263 μ broad, red-brown; membrane of mature oospores has granulate reticulation; antheridia are up to 360 μ in diameter.

Apparently not cited for the state until the present report.

Specimens seen: JACKSON COUNTY: Small pool of water in seepage on sand, below dam at Starve Hollow Lake, Driftwood State Fish Hatchery near Valonia, *W. A. & F. K. Daily* 268, Aug. 26, 1950 (BU). SULLIVAN COUNTY: Shakamak State Park, west side of Shakamak Lake, *Robert Filkins* and *R. N. Webster*, Apr. 20, 1952 (BU).

5. NITELLA TENUISSIMA (Desv.) Kütz. Phyc. Gen., p. 319. 1843.

Habit small compact, internodes ca. 2-5 times the length of the branchlets; monoecious; whorls of usually 6 short, compact branchlets; branchlets usually 3 times furcate (4); primary rays $\frac{1}{3}$ - $\frac{2}{5}$ the entire length of the branchlet; usually 6 or 7 secondary rays at the first furcation, usually 4-6 tertiary rays at the second furcation; some tertiary rays again furcate producing usually 3-5 quarternary rays; quaternary rays sometimes producing 3-4 quinary rays; ultimate rays 2-celled with the ultimate cell acuminate, slender; fruiting bodies in all but the first furcation of the branchlet, solitary; oospores usually 200-250 μ long (up to 265-315 μ in var. *compacta*) 235-290 μ broad, with 7-9 ridges, brown; outer oospore membrane red-brown, with beaded reticulation; antheridia up to 265 μ in diameter.

NITELLA TENUISSIMA var. COMPACTA A. Br. Abh. Kön. Akad. Wiss. Berlin, p. 62. (1882) 1883.

See *Nitella tenuissima* in Daily (10) for illustration.

This variety has been characterized by its small size and the very compact nature of the branchlets, which are usually only ca. 1-3 mm. long in Indiana specimens. Some oospores are larger than the previously given range.

All collections of this species so far made in Indiana seem to fit the description for var. *compacta*.

Included here are the specimens from Marshall County which probably are the basis of the report by Evermann and Clark (15) whose study was also cited by Palmer (27) in which *Nitella tenuissima* was found in Lake Maxinkuckee and "common in Lost Lake." Also included is the specimen which is the basis of the report of Evermann and Clark (15) cited also by Palmer (27) of *N. batrachosperma* from Lake Maxinkuckee, Marshall County. Included also is the specimen which is the basis of the report by Palmer (28) for Steuben County cited as follows: "*Nitella tenuissima* Kütz.; Bass L., July."

Specimens seen: KOSCIUSKO COUNTY: Shallow water near shore, marl bottom, Dewart Lake, *M. S. Markle* 8, Aug., 1946 (EC, BU); in shallow water on bottom of a recently excavated channel, southeast border of Chapman Lake, *R. C. Friesner* 23168, Sept. 24, 1949, 23207, Oct. 8, 1949 (BU); on turf in shallow water, Lake Wawasee, near Johnson's Hotel, *W. A. & F. K. Daily* 199, July 23, 1950 (CM, HafR, BU); on turf, shallow water, Lake Wawasee, west of Johnson's Hotel, *W. A. & F. K. Daily* 234, 235 with *C. contraria*, July 26, 1950 (CM, BU). MARSHALL COUNTY: Muddy bottom, north end of Lost Lake, *B. W. Evermann* 1574 (570), Sept. 1900 (USM, BU) (Probably the basis of the report of Evermann and Clark, 15, and Palmer, 27); not seen in habitat—found among material from Lost Lake, *B. W. Evermann* 1576 (578), about Sept. 19, 1900 (USM, BU) (the basis of the report in Evermann and Clark, 15, and Palmer, 27, of *N. batrachosperma*); common near shore, Lake Maxinkuckee, *B. W. Evermann* 1578 (608), Oct. 12, 1900 (USM, BU) (Possibly the basis of the report in Evermann and Clark, 15, and Palmer, 27). STEUBEN COUNTY: Shallow water near bank attached to bottom in groups, Bass Lake, *C. M. Palmer* 1007, July 28, 1933 (BU) (The basis of the report by Palmer, 28); in tufts on marl bottom, shallow water ca. 1 ft. deep, Green Lake, *W. A. & F. K. Daily* 160, Sept. 10, 1947 (CM, HafR, BU). 6. NITELLA MEGACARPA T. F. Allen. Char. Amer. Exsicc. 3. 1880. (Description).

Habit robust, spreading; branchlets usually 5-6 in a whorl, 3-4 times furcate with usually 5 secondary rays at the first furcation, 2 or 3 at the second furcation, 2 or 3 at the third furcation, and 2-4 at the fourth furcation when it occurs in some of the quaternary rays; ultimate rays usually 2-celled, but also 3-celled (4), variable in size from very short to quite long; ultimate cell conical and mucronate; oogonia in all furcations of the branchlets except the last one especially when a crown of short ultimate rays are produced; coronula of the oogonium short; oospores usually 370-400 μ long, ca. 318-368 μ broad, with 6 or 7 ridges; outer oospore membrane with granules connected by reticulation; antheridia ca. 265 μ in diameter. (Although the oospores do not reach the proper size in two collections, they are probably immature judging from color and difficulty in removing from the plant, otherwise Indiana collections agree in essential characteristics with a co-typic collection seen by the author.)

Specimens which probably form the bases of the report of *Nitella mucronata* from Marshall County in Evermann and Clark (15) whose record was cited by Palmer (27) were redetermined *Nitella megacarpa* T. F. Allen. Two locations were cited by Evermann and Clark. They state, "A delicate species growing in the muddy bottom of Lost Lake. One of the most attractive species of the region. Abundant at Bass Lake."

Specimens seen: MARSHALL COUNTY: *B. W. Evermann 1571* (374), Aug. 13, 1900 ? (USM, BU); *B. W. Evermann 1583* (708) (USM, BU) (no collection data accompanied this but it possibly is the basis for the report for Lost Lake in Evermann and Clark, 15, and Palmer, 27, as the determination *N. mucronata* was on the specimen.) PORTER COUNTY: Dredged collection, Moss Lake, $\frac{1}{2}$ mi. west of Lake Wauhob near Valparaiso, *W. A. & F. K. Daily 365*, Aug. 30, 1951 (BU). STARKE COUNTY: Bass Lake, *H. W. Clark & B. W. Evermann 132*, Aug. 14, 1906 (CM, USM, BU) (probably the basis of the report in Evermann and Clark, 15, for *N. mucronata* for Bass Lake as this determination was with the specimen).

III. CHARA (Vaill.) Leonh.

7. CHARA BRAUNII Gmel. Fl. Bad. Alsat. 4:646. 1826. (As a synonym, *Chara coronata* Ziz.)

See *Chara coronata* in Daily (6) for general description and illustrations.

Because of intergradation in this species, it is difficult to exactly distinguish the varieties as established, so that use of varietal names is unsatisfactory. In Indiana specimens, there is a great variation in habit from short and tufted to elongate, in stipulodes from very short and slender to long and broad, in bract cells from unilateral to verticillate, in oospore length from 500-578 μ . The number of ridges on the oospore is usually 9, however, and the bracteoles and anterior bract cells are usually longer than the oogonia. If limited to a consideration of the last two characteristics and oospore length, Indiana plants are all referable to var. *Schweinitzii*, but the range of other characteristics is not encompassed in this category. Varietal names are, therefore, not considered in this species for the present.

Specimens seen: BROWN COUNTY: Dredged collection, Lake Ogle, Brown County State Park, *Mary Fritsche*, *W. A. & F. K. Daily* 172, Sept. 19, 1947 (CM, HafR, BU). JACKSON COUNTY: On sand in seepage at dam, Starve Hollow Lake, Driftwood State Fish Hatchery, near Valonia, *W. A. & F. K. Daily* 269, Aug. 26, 1950 (BU); small pond below dam, Driftwood State Fish Hatchery, near Valonia, *W. A. & F. K. Daily* 271, Aug. 26, 1950 (CM, BU); pond northeast of parent pond, Driftwood State Fish Hatchery, near Valonia, *W. A. & F. K. Daily* 272, Aug. 26, 1950 (CM, HafR, BU). KOSCIUSKO COUNTY: With *C. contraria*, Ridinger Lake, *J. T. Scovell* (2-5), Sept. 4, 1904 (USM, BU); dredged collection, pond, Wawasee Fish Hatchery, *W. A. & F. K. Daily* 215, July 23, 1950 (CM, HafR, BU); with *C. contraria*, in shallow water, Lake Wawasee, west of Johnson's Hotel, *W. A. & F. K. Daily* 235, July 26, 1950 (CM, BU); in ca. 6 ft. of water, Lake Wawasee at Turkey Creek Inlet, *W. A. & F. K. Daily* 239 (BU), 241 (CM, HafR, BU), July 26, 1950. LAKE COUNTY: Shallow water near east shore of Wolf Lake, opposite park at south end of Whiting, *R. C. Friesner* 21126, Sept. 28, 1946 (BU). MARSHALL COUNTY: On peat in shallow water, Lost Lake (Hawk's Pond), *W. A. & F. K. Daily* 106, July 3, 1946 (BU). PORTER COUNTY: In shallow water with sandy bottom and boggy shore, Lake Eliza, 6 mi. west and 3 mi.

south of Valparaiso, *W. A. & F. K. Daily* 360, Aug. 30, 1951 (CM, HafR, GOA, BU); sandy bottom, Flint Lake, Black Hawk Beach, 2½ mi. north of Valparaiso, *W. A. & F. K. Daily* 361, Aug. 30, 1951 (BU); Spectacle Lake, ca. 1 mi. west of Flint Lake, north of Valparaiso, *W. A. & F. K. Daily* 366, Aug. 30, 1951 (GOA, BU). STEUBEN COUNTY: Hamilton Lake, Circle Park, *W. A. & F. K. Daily* 288A with *C. contraria* (CM, GOA, BU), 288B with *C. Kieneri* (GOA, BU), June 17, 1951; Lime Lake, east side, *W. A. & F. K. Daily* 307 (CM, GOA, BU), 308 with *C. contraria*, June 18, 1951.

For further citation of specimens see Daily (7) under the name, *Chara coronata* Ziz. In that study, collections were reported from Martin and Porter Counties.

8. *CHARA BRITTONII* T. F. Allen ex Robinson. *Bul. N. Y. Bot. Gard.* 4(13): 295. 1906.

Plate II-D

Habit short and compact, usually not more than 2 cm. in height with branchlet whorls overlapping; monoecious, but antheridia and oogonia usually at different nodes of the branchlet; stem and branchlets entirely ecorticate; stipulodes in 2 series in a circle around the stem, quite long and narrow, upper series ca. 636-1,166 μ long, lower series 636-1,590 μ long; branchlets usually bearing 2 or 3 nodes having long bracts and bracteoles, followed by a 2-celled tip; oospores 682-782 μ long, black, having 15 ridges; antheridia 265-318 μ in diameter.

See Daily (7) for citation of specimens. In that study, reports were made for Randolph and LaPorte Counties. These are the specimens cited by Friesner and Potzger (16 and 17).

Apparently previously to the Indiana collections, this species had been known only from the type collection which has been examined by the author. Indiana material is very similar.

Specimens may be found at Harvard University, U. S. National Museum, New York Botanical Garden, Chicago Natural History Museum, and Butler University. These were collected from Randolph County. La Porte County specimens are at Butler University.

9. *CHARA KEUKENSIS* (T. F. Allen) Robinson. *Bul. N. Y. Bot. Gard.* 4: 273. 1906. (As synonym, *Chara gymnopitys* var. *keukensis* T. F. Allen. *Bul. Torrey Bot. Club* 20: 120. 1893.)

Plate II-E

Habit short, compact; monoecious; stem cortication diplostichous, primary cortical cells usually prominent, irregular with secondary cells sometimes produced on both sides of node, but extending only a short distance; spine cells variable, from papillae to ca. 900 μ in length; stipulodes in a single series in a circle around the stem, up to twice the number of the branchlets, from ca. 800-1,325 μ in length; branchlets usually 8-10 in a whorl of 5 or 6 entirely ecorticate segments; bract cells usually longer than the oogonia; bracteoles similar to the bracts; oospores black, from 345-450 μ in length, 265-290 μ broad, with 9-11 ridges; antheridia up to ca. 300 μ in diameter.

Included here is the specimen reported by Palmer (28) from Steuben County as, "*Chara delicatula* var. *annulata* (Wallman) G. and B. W.; Crooked L., Sept. A small form growing in shallow water along the shore line."

Indiana material is very similar to the specimen of *Chara keukensis* borrowed from the New York Botanical Garden for which the citation follows: *Phycotheca Boreali Americana*, Collins, Holden & Setchell 1491, Lake Keuka, N. Y., collected by T. F. Allen, determined by C. B. Robinson.

Specimens seen: JACKSON COUNTY: Moist sand at dam of Starve Hollow Lake, Driftwood State Fish Hatchery, near Valonia, *W. A. & F. K. Daily* 267, Aug. 26, 1950 (CM, HafR, BU). STEUBEN COUNTY: Margin, Crooked Lake, *C. M. Palmer* B51, Sept. 30, 1933 (BU) (Basis of the report of *C. delicatula* var. *annulata* from Crooked Lake by Palmer, 28).

For further citation of specimens see Daily (7) under the name, *Chara gymnopitys*. As varietal names were avoided in that study and since this species seemed more consistently arranged as a variety of *Chara gymnopitys*, only that name appeared. It is possible that further collections may produce substantiating evidence supporting Allen's original conviction that this should be considered a variety of *C. gymnopitys* (*C. fibrosa* Ag. ex Bruz. has precedence over *C. gymnopitys* according to Zaneveld, 43).

Specimens were reported in Daily (7) from Cass, Lake, and LaPorte Counties. A specimen also reported in that study from Morgan County must be included with *C. hydropitys*.

No specimens were seen to support the report of *Chara gymnopitys* in Evermann and Clark (15) and Palmer (27).

10. CHARA HYDROPITYS Reich. in Mössler. Gemein. Handb. d. Gewächsk., p. 1600. 1829. (*C. hydropithys* originally by error. *Fide* Horn af Rantzien, 20).

Habit compact or extended; monoecious; stem essentially diplostichous, sometimes partially triplostichous by development of secondary cortical cells on both sides of the node, but some extending only a short distance, primary cells prominent; spine cells papillate to very long, branchlets partially diplostichally corticated with the lowest segment ecorticate and tipped by usually 2 or 3 ecorticate segments, the last surrounded by a tuft of long bract cells, occasionally some of the branchlets entirely ecorticate; bracts and bracteoles quite long; stipulodes in a single series in a circle around the stem, quite long; antheridia and oogonia solitary and together at the lowest nodes of the branchlets.

There is considerable variation in this group and the limits of present varieties seem to overlap. However, Indiana plants collected so far possibly are all referable to the following variety:

CHARA HYDROPITYS var. SEPTENTRIONALIS Nordst. Char. Am. Exsicc. 10. 1882. T. F. Allen (As synonym, *C. hydropitys* var. *majuscula* Nordst.)

Plate II-F

Ca. 8-10 branchlets per whorl; usually 5 or 6 segments per branchlet; stipulodes 500-1,200 μ long; spine cells from papillate to ca. 950 μ in length; oospores (371 μ long, brown, immature?) 424-477 μ in length, 265-292 μ broad, black, with (10) 11-13 ridges; antheridia up to ca. 265 μ in diameter.

Included here is the plant reported in Daily (7) as *C. gymnopitys* from Morgan County. The infrequent production of corticated branchlet segments and their transparency caused difficulty in identification.

Specimens seen: JACKSON COUNTY: On moist sand, at dam of Starve Hollow Lake, Driftwood State Fish Hatchery, near Valonia, *W. A. & F. K. Daily* 267, with *C. keukensis* 270, Aug. 26, 1950 (CM, HafR, BU); fish breeding pond, first pond northeast of parent pond, Driftwood State Fish Hatchery, near Valonia, *W. A. & F. K. Daily* 273, Aug. 26, 1950 (CM, BU). MARSHALL COUNTY: Marsh. west shore of Lost Lake, *B. W. Evermann* 1575 (574), Sept. 1900 (USM, BU). MORGAN COUNTY: In shallow water at

pool's edge, Jewel Lake, Bethany Park, near Martinsville, *W. A. & F. K. Daily* 37, Sept. 20, 1942 (BU) (Reported in *Daily*, 7, as *C. gymnopitys*).

For further citation of specimens see *Daily* (7). In that study, collections were reported from Lake, Porter and Wayne Counties.

11. *CHARA EXCELSA* T. F. Allen. *Bul. Torrey Bot. Club.* 9(4): 43. Apr., 1882.

Plate II-G

Habit similar to *C. contraria* but more slender and spinescent; monoecious; branchlets usually 7-8 at a verticel, having 3 or 4 doubly corticated internodes and 2 or 3 ecorticate cells at the tip; stem cortex diplostichous but irregular often producing an additional short secondary cell or having the ends of secondary cells overlapping so that the cortex is occasionally triplostichous; spine cells undeveloped up to very long found sometimes on the same stem internode; stipulodes variable in size and shape at the same verticel, in 2 series in a circle around the stem at the base of a branchlet whorl; bracteoles and anterior bracts usually slender and exceeding the oogonia; posterior bracts much shorter, variable, sometimes as short as in *C. contraria* but usually longer and more slender; oogonia with elongated neck and short coronula; oospores black, 685 μ long and 370 μ broad with 15 or 16 ridges; antheridia up to 370 μ in diameter.

Indiana material seems essentially the same as the cotypic material seen by the author. This species apparently has not been reported for the state previously.

Specimens seen: KOSCIUSKO COUNTY: In shallow water, Dewart Lake, *W. A. & F. K. Daily* 187, July 10, 1949 (CM, BU); with *C. contraria* behind Johnson's Hotel Annex, in inlet, Lake Wawasee, *W. A. & F. K. Daily* 209, July 23, 1950 (CM, HafR, BU). STEUBEN COUNTY: Shallow water, Silver Lake, ca. 3 mi. west of Angola on U. S. Rd. 20, *W. A. & F. K. Daily* 331 and 336 with *C. contraria*, June 20, 1951 (BU).

12. *CHARA KIENERI* *Daily*. *Butler Univ. Bot. Stud.* 9: 127-130. 1949.

See *Daily* (9) for description and illustrations.

Some interesting observations concerning the occurrence of forked anterior bract and bracteole cells as well as other forked processes in *Chara* have come to the author's notice since publication of the

species, *Chara Kieneri*. G. O. Allen (1) reported bifid bracteoles and bract cells in a plant referred to *Chara aspera*. Material kindly supplied by Dr. Allen proved to have also divided spine cells. Other material awaits further data for reporting. The question must be considered whether these occurrences should be construed in all cases as abnormalities or if they are taxonomically significant.

It was arranged by Dr. J. E. Potzger for specimens of *Chara Kieneri* to be collected from the same location in Michigan for two successive years and the characteristic of forked bracteoles and anterior bract cells was constant in both collections.

Although forked processes may be infrequent on a plant of *Chara Kieneri*, the general habit, accompanied by the extremely irregular cortex, and the occasionally geminate spine cells are enough to stimulate a search usually rewarded by finding some of the forked members, and to differentiate the plant from *Chara excelsa* with which it is most closely allied.

Specimens seen: CLAY COUNTY: Water in old strip mine on Rd. 46, ca. 2 mi. west of Bowling Green, *W. A. & F. K. Daily* 285, May 5, 1951 (CM, HafR, BU). KOSCIUSKO COUNTY: With *C. contraria*, south side of Center Lake, Warsaw, *W. A. & F. K. Daily* 195, July 22, 1950 (CM, HafR, BU); dredged collection in shallow water, inlet on west side of Lake Wawasee on Rd. 13 near Lake Dr., Conklin's Bay, *W. A. & F. K. Daily* 217, July 24, 1950 (BU). LAWRENCE COUNTY: Avoca State Fish Hatchery, *W. A. & F. K. Daily* 252 in pond nearest station (CM, HafR, BU), 253 in second pond from station toward road (CM, HafR, BU), 254 fish pond south of Goose Creek (CM, BU), Aug. 1, 1950. NEWTON COUNTY: Shallow pools, at edge of gravel pit pond, rt. side of first road west paralleling Rd. 41, ca. 3 mi. north of Ade, *W. A. & F. K. Daily* 358, Aug. 28, 1951 (BU); gravel pit pond, dredged collection, ca. 3 mi. north of Ade, rt. side of first road west paralleling Rd. 41, *W. A. & F. K. Daily* 359 with *C. globularis*, Aug. 28, 1951 (CM, HafR, GOA, BU). STEUBEN COUNTY: Dredged collection, Circle Park, Hamilton Lake, *W. A. & F. K. Daily* 288B, June 17, 1951 (GOA, BU); dredged collection, Lake James on southwest side, Bayou slightly southeast of Spring Point, Lower Basin, *W. A. & F. K. Daily* 314 and 317 (CM, GOA, BU), 315 (CM, HafR, GOA, BU), June 19, 1951; shallow water, east of bridge over canal between Middle Basin of Lake James and Jimerson Lake, *W. A. &*

F. K. Daily 320, June 19, 1951 (CM, GOA, BU) ; shallow water west of bridge over canal between Jimerson Lake and Middle Basin of Lake James, *W. A. & F. K. Daily* 321, June 19, 1951 (CM, HafR, GOA, BU) ; shallow water, Display Pond, Pokagon State Park, *W. A. & F. K. Daily* 323 (CM, HafR, BU), 324 (BU), 325 (CM, BU), June 19, 1951; dredged collection in shallow water, Silver Lake, ca. 3 mi. west of Angola on U. S. Rd. 20, *W. A. & F. K. Daily* 334A (CM, GOA, BU), 334B with *C. contraria* (CM, GOA, BU), 337 (BU), 338 with *C. aspera* var. *Macounii* (CM, BU), June 20, 1951.

13. *CHARA CONTRARIA* A. Br. ex Kütz. Phyc. Germ., p. 258. 1845.
See Daily (6) for description and illustrations.

Since there are many intergrading forms in this taxon, it is very difficult to differentiate the varieties *moniliformis* and *hispidula* as is sometimes done on the basis of short and long spine cells respectively; so these varietal names are not employed here.

Included here are the specimens reported in Evermann and Clark (15) for Lake Maxinkuckee, Marshall County, whose study was also cited in Palmer (27). Evermann and Clark reported, "This is the most common *Chara* in the lake, forming extensive meadows over the bottom. . . . According to Dr. Robinson, 'this is a very polymorphic form, several of our specimens representing the common American form, a few being more robust and heavily encrusted, others usually slender and another form with very short whorls. Again, one specimen was peculiar in appearing, through hypertrophy of the secondary rows of cortex, to be triply corticated.'" Further in the work they said, "It forms a covering over most of the bottom of Outlet Bay out from Long Point, and, indeed, almost everywhere in the lake where bottom and depth are favorable."

Also included here are the specimens probably indicated in the manuscript by J. T. Scovell (39) on Twin Lakes, Marshall County, to be found in the Indiana Historical Section of the Indiana State Library. They were referred to by genus name only from "The Dam" of Twin Lakes, Treighbaum Lake and Pretty Lake.

One specimen constituting the basis of the report by R. C. Friesner and J. E. Potzger (17) from Randolph County is included here. Another was reported by Daily (7).

The specimen reported by Palmer (28) from Bass Lake, Steuben County, as *Chara fragilis* is also included here.

Specimens seen: BARTHOLOMEW COUNTY: Ponds at overpass on Rd. 31 near Columbus, *W. A. & F. K. Daily* 61, (CM, BU), 62 with *C. globularis* (CM, BU), 63 with *C. globularis* (BU), 64 and 65 (CM, BU), 66 (BU), 67 (CM, HafR, BU), 68 (CM, BU), 69 with *C. globularis* (CM, BU), 70 and 72 (CM, HafR, BU), 71 (CM, BU), July 12, 1945; in shallow water of old oxbows of White River, just north of Rd. 31 overhead ca. 2 mi. north of Columbus, *R. C. Friesner* 20929, 20930, Aug. 3, 1946 (BU). BOONE COUNTY: Shallow water in pond, at north end of bypass on Rd. 52 around Lebanon on west side of road at overpass over N. Y. Central railroad track, *C. T. Kenoyer, W. A. & F. K. Daily* 370, Sept. 29, 1951 (CM, HafR, BU). CASS COUNTY: A short form on a springy place on marly flat near the northeast corner of Peabody Bog, ca. 3.5 mi. northeast of Hoovers, *R. C. Friesner* 20603 with *C. vulgaris*, 20606, June 22, 1946 (BU). CLAY COUNTY: A dredged collection from Orchard Lake, north of Clay City, *F. Geisler, F. Hueber, W. A. & F. K. Daily* 277, Sept. 23, 1950 (CM, HafR, BU); pond in abandoned strip mine 1 mi. north of crossroads of Rds. 59 and 46, *F. Geisler, F. Hueber, W. A. & F. K. Daily* 280, Sept. 23, 1950 (CM, HafR, BU); pond in strip mine on east side of road ca. 2 mi. south of Rd. 42 and ca. 2 mi. north of Center Point, *W. A. & F. K. Daily* 350, 351, Aug. 26, 1951 (CM, GOA, BU); dredged collection from water of old strip mine pond at Zenor Pit, 1½ mi. southeast of Center Point, *W. A. & F. K. Daily* 352A, Aug. 26, 1951 (HafR, GOA, BU). ELKHART COUNTY: In shallow water, east shore of Simonton Lake, *R. C. Friesner* 19060, June 17, 1945 (BU). FULTON COUNTY: Nyona (North Mud Lake), ca. 4 mi. east of Fulton, *W. A. & F. K. Daily* 82 on muck bottom in 1 or 2 ft. of water, 83 dredged from deeper water, June 29, 1946 (CM, HafR, BU); muck bottom of South Mud Lake, 4 mi. east of Fulton, *W. A. & F. K. Daily* 85, June 29, 1946 (CM, HafR, BU). HANCOCK COUNTY: From water in drainage ditch, 2 mi. north and 1½ mi. east of Eden, *J. E. Potzger* 9693, Aug. 5, 1944 (BU). HARRISON COUNTY: Water in old rock quarry on south side of Rd. 62 ca. 2½ mi. east of Corydon, *C. C. Deam* 63506, Aug. 22, 1945 (BU); shallow water in old limestone quarry along Rd. 62, 1.9 mi. east of Corydon, *R. C. Friesner* 19558, 19559 with *C. zeylanica* f. *Michauxii*, Sept. 1, 1945 (BU); water in quarry, 1½ mi. east of Corydon on Rd. 62, *C. M. Palmer, W. A. & F. K. Daily* 139 (CM,

BU), 141 (CM, HafR, BU), May 10, 1947. JAY COUNTY: Large pond at overpass a short distance southwest of Red Key on Rd. 67, *W. A. & F. K. Daily* 286, June 16, 1951 (CM, HafR, BU). KOSCIUSKO COUNTY: James Lake, part of Tippecanoe Lake system, *J. T. Scovell* (3-7) in shallow water with *C. aspera* var. *Macounii*, (3-11) in 3-7 ft. of water, June 25, 1904 (USM, BU); 4-8 ft. of water, Tippecanoe Lake, *J. T. Scovell* (3-18), July 25, 1904 (USM, BU); 4-8 ft. of water, Lake Tippecanoe, *J. T. Scovell* (3-17), July 26, 1904 (USM, BU); 16-18 ft. of water, Dan Kuhn Lake, *J. T. Scovell* (3-5), July 27, 1904 (USM, BU); Ridinger Lake, *J. T. Scovell* (2-4), (2-5), Sept. 4, 1904 (USM, BU); My Gal Cottage, northwest portion of Tippecanoe Lake, *H. B. Metcalf* 1, Oct. 12, 1947 (BU); in ca. 3 ft. of water in small inlet on east side of Barbee Lake, *R. C. Friesner* 22260, 22261, July 10, 1948 (BU); near pier of Quaker's Retreat in shallow water, Dewart Lake, *W. A. & F. K. Daily* 174 (CM, HafR, BU), 175 (CM, BU), July 9, 1949; dredged collection from Dewart Lake, *W. A. & F. K. Daily* 176 (CM, BU), 177 and 178 (CM, BU), 179 (CM, HafR, BU), 180 with *C. aspera* var. *Macounii* (BU), 182 with *C. globularis* (CM, HafR, BU), 183 (CM, BU), July 9, 1949, 185 (CM, HafR, BU), 187 with *C. excelsa* (CM, BU), 188 with *C. globularis* (BU), 189 with *C. globularis* (CM, BU), 190 (BU), July 10, 1949; in shallow water of an excavated channel, southeast side of Chapman Lake, *R. C. Friesner* 23167, Sept. 24, 1949 (BU); ca. 3 ft. of water, Hill Lake (formerly Homan Lake), *W. A. & F. K. Daily* 192, July 22, 1950 (CM, HafR, BU); dredged collection, south side of Carr Lake at Brown's Landing, *W. A. & F. K. Daily* 193, July 22, 1950 (CM, HafR, BU); dredged collection from the east side of Goose Lake, *W. A. & F. K. Daily* 194, July 22, 1950 (CM, HafR, BU); south side of Center Lake, Warsaw, *W. A. & F. K. Daily* 195, July 22, 1950 (CM, HafR, BU); in shallow water, Winona Lake, *W. A. & F. K. Daily* 196 with *C. zeylanica* f. *Michauxii*, July 23, 1950 (CM, BU); Lake Wawasee at pier of Johnson's Hotel, *W. A. & F. K. Daily* 197 with *C. globularis*, July 23, 1950 (CM, HafR, BU); behind annex of Johnson's Hotel in shallow water of Lake Wawasee, *W. A. & F. K. Daily* 200 (CM, HafR, BU), 201 with *C. aspera* var. *Macounii* (CM, HafR, BU), 203 (CM, BU), 204 and 205 (CM, HafR, BU), 206 with *Nitella flexilis* var. *subcapitata* (BU), 207 and 208 (CM, BU), 209 and 210 (CM, HafR, BU), July 23, 1950; dredged collection, Lake Wawasee

near outlet of Wawasee Fish Hatchery, *W. A. & F. K. Daily* 211, July 23, 1950 (CM, HafR, BU); dredged collection, Syracuse Lake at Syracuse City Park Pier, *W. A. & F. K. Daily* 212, 213, July 23, 1950 (CM, HafR, BU); pond at Wawasee Fish Hatchery, *W. A. & F. K. Daily* 214 (CM, BU), 215 with *C. Braunii* (CM, HafR, BU), July 23, 1950; shallow water, east of Wawasee Fish Hatchery, Lake Wawasee, *W. A. & F. K. Daily* 216, July 23, 1950 (CM, BU); inlet on west side of Lake Wawasee, Rd. 13 near Lake Dr., Conklin's Bay, *W. A. & F. K. Daily* 217 with *C. Kieneri*, July 24, 1950 (BU); in channel between Lake Wawasee and Lake Syracuse, *W. A. & F. K. Daily* 219, July 24, 1950 (CM, HafR, BU); dredged collections, Sturm and Dillard gravel pit pond near the B. & O. railroad tracks, 2.5 mi. west of Syracuse, *W. A. & F. K. Daily* 220 and 221 (CM, HafR, BU), 220A with *C. globularis* (CM, BU), 222 (BU), July 24, 1950; in ca. 3½ in. of water, shallow pools along railroad track at Sturm and Dillard Gravel Pit, 2.5 mi. west of Syracuse, *W. A. & F. K. Daily* 223, July 24, 1950 (CM, HafR, BU); dredged collection from Hammond Lake, *W. A. & F. K. Daily* 224, July 25, 1950 (CM, HafR, BU); dredged collection from Allen Lake, *W. A. & F. K. Daily* 225, July 25, 1950 (BU); dredged collection from Shock Lake, *W. A. & F. K. Daily* 226, July 25, 1950 (CM, BU); dredged collection from Lake Webster, *W. A. & F. K. Daily* 227, July 25, 1950 (CM, HafR, BU); dredged collection from Upper Tippecanoe Lake (Little Tippecanoe, James Lake), *W. A. & F. K. Daily* 228, 229, 231, July 25, 1950 (CM, HafR, BU); shallow water, Lake Wawasee, west of Johnson's Hotel, *W. A. & F. K. Daily* 232 with *C. aspera* var. *Macounii* (CM, HafR, BU), 233 (CM, HafR, BU), 234 with *N. tenuissima* var. *compacta* (CM, BU), 235 (CM, BU), July 26, 1950; shallow water east of Johnson's Hotel at Turkey Creek Inlet, Lake Wawasee, *W. A. & F. K. Daily* 236 and 238 (CM, BU), 237 (BU), 239 with *C. Braunii* (BU), 240 (CM, HafR, BU), July 26, 1950; shallow water, north shore of Big Barbee Lake, *W. A. & F. K. Daily* 242, July 27, 1950 (CM, BU); Durham Lake (Daniel's Lake) several mi. southeast of North Webster, *W. A. & F. K. Daily* 243 with *C. zeylanica* f. *Humboldtiana* (BU), 244 with *C. globularis* (CM, BU), 245 (CM, BU), July 27, 1950; Kuhn Lake, *W. A. & F. K. Daily* 246 with *C. aspera* var. *Macounii*, July 27, 1950 (CM, HafR, BU); dredged collections, Ridinger Lake, *W. A. & F. K. Daily* 247 with *C. zeylanica* f. *Michauxii* (CM, HafR, BU), 248 (CM, BU),

July 27, 1950; west side of Big Barbee Lake, *W. A. & F. K. Daily* 249, July 27, 1950 (CM, HafR, BU); dredged collections, Lake Papakeechee, *F. K. Daily* 250, 251, July 28, 1950 (CM, HafR, BU). LAKE COUNTY: Marly margin of slough, ca. 0.2 mi. south of Pine Station on Clarke St., Gary, *R. C. Friesner* 21039, 21041, Sept. 14, 1946 (BU); shallow water near east shore of Wolf Lake, opposite the park in the south end of Whiting, *R. C. Friesner* 21125, Sept. 28, 1946 (BU). LAWRENCE COUNTY: Dredged collection, Spring Mill Lake, Spring Mill State Park, *W. A. & F. K. Daily* 172A, June 29, 1948 (CM, HafR, BU); southernmost pond, Avoca State Fish Hatchery, *W. A. & F. K. Daily* 255, Aug. 1, 1950 (CM, BU). MARION COUNTY: Pool 8, Riverside Fish Hatcheries, *Camellia Kenoyer*, *W. A. & F. K. Daily* 128, Sept. 2, 1946 (BU); near shore of gravel pit pond, Standard Material Co., 4100 E. 56th St., Indianapolis, *W. A. & F. K. Daily* 341 (CM, HafR, BU), 342 and 343 (BU), July 14, 1951; pond, Holliday Park, Indianapolis, *W. A. & F. K. Daily* 371, Feb. 9, 1952 (CM, BU). MARSHALL COUNTY: Grew in laboratory of J. T. Scovell Sept., 1903-Sept., 1904, originally from Lake Maxinkuckee, *J. T. Scovell* (2-11), Sept. 1903 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer, 28); "The Dam" of Twin Lakes, *J. T. Scovell* (3-12), July 6, 1904 (USM, BU) (Probably the basis for the report of Chara in Scovell, 39); in ca. 3 ft. of water, Meyer's Lake, *J. T. Scovell* (3-6), July 7, 1904 (USM, BU); 3-6 ft. of water, Treighbaum Lake, *J. T. Scovell* (3-10), July 8, 1904 (USM, BU) (Probably the basis of the report of Chara in Scovell, 39); Pretty Lake, *J. T. Scovell* (3-14, 3-14x, 3-14xx) with *C. globularis*, July 21, 1904 (USM, BU) (Probably the basis of the report of Chara in Scovell, 39); 11 ft. of water on south end of lake bar north of the Maxinkuckee line, Lake Maxinkuckee, *J. T. Scovell* (3-21), July 30, 1904 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer 27); 10-12 ft. of water, east lake bar, dark marl mud, just north of the Maxinkuckee line, *J. T. Scovell* (3-23), July 30, 1904 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer, 27); 8 ft. of water, dark marl mud, west side of Long Point bar on the Maxinkuckee line, *J. T. Scovell* (3-22), July 30, 1904 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer, 27); shallow water near the Point, Lake Maxinkuckee, *J. T. Scovell* 8A and 8B

(3-8), July 30, 1904 (USM, BU) (Probably the basis for the report in Evermann and Clark, 15, and Palmer, 27); dark marl, 8 ft. of water, Lake Maxinkuckee, *J. T. Scovell* (3-24), July 30, 1904 (USM, BU) (Probably the basis of the report in Evermann and Clark 15, and Palmer, 27); 6-8 ft. of water, Lake Maxinkuckee, *J. T. Scovell* (3-20a), (3-20b), Aug. 2, 1904 (USM, BU) (Probably the bases of the reports in Evermann and Clark, 15, and Palmer, 27); Houghton Lake, 2 mi. northwest of Culver off Rd. 10, Maxinkuckee Gun Club and Fish Hatchery, *W. A. & F. K. Daily* 86 (BU), 87 and 88 (CM, BU), July 1, 1946; ponds, 2 mi. northwest of Culver off Rd. 10, Maxinkuckee Gun Club and Fish Hatchery, *W. A. & F. K. Daily* 89 (CM, BU), 90 (CM, HafR, BU), 91 (BU), 94 and 96 (CM, HafR, BU), July 1, 1946; drainage ditch, 2 mi. northwest of Culver, Maxinkuckee Gun Club and Fish Hatchery, *W. A. & F. K. Daily* 92 with *C. vulgaris* (CM, HafR, BU), 95 (CM, BU), July 1, 1946; shallow water, Long Point, Lake Maxinkuckee, *W. A. & F. K. Daily* 97 with *C. aspera* var. *Macounii*, July 2, 1946 (CM, HafR, BU); shallow water, Lost Lake (Hawk's Pond), *W. A. & F. K. Daily* 98 with *C. aspera* var. *Macounii* (CM, BU), 99 (CM, HafR, BU), 104 and 107 (CM, HafR, BU), 100 (CM, BU), 102 and 103 (CM, BU), July 3, 1946; shallow water near inlet and Farrar's Woods, Lake Maxinkuckee, *W. A. & F. K. Daily* 109 and 110 (CM, HafR, BU), 111 (CM, BU), 112 (BU), 113 with *C. globularis* (CM, HafR, BU), 114 with *C. aspera* var. *Macounii* (CM, BU), July 4, 1946; shallow water, Rossa's Pier, Lake Maxinkuckee, *W. A. & F. K. Daily* 116 with *C. globularis* (CM, HafR, BU), 117 (BU), July 5, 1946; mud bottom, water ca. knee deep, water plants growing densely, Lake Maxinkuckee Outlet, *Russell Fisher*, *W. A. & F. K. Daily* 118, July 5, 1946 (CM, HafR, BU); Lost Lake, *Russell Fisher* A, July 8, 1946 (BU); shallow water, muck bottom, Old Outlet, Lake Maxinkuckee, *Russell Fisher* with *C. delicatula*, July 8, 1946 (BU). NOBLE COUNTY: Dredged collection, Cree Lake, *W. A. & F. K. Daily* 150, Sept. 9, 1947 (BU). RANDOLPH COUNTY: Flowing water in ditch, Cabin Creek Bog, along Rd. 1, 6 mi. north of Modoc, *R. C. Friesner* 18786, Dec. 9, 1944 (BU) (One of the specimens forming the basis for the report of Friesner and Potzger, 17). ST. JOSEPH COUNTY: St. Joseph Lake, Notre Dame Univ. Campus, Notre Dame, *Noe and Betty Higinbotham*, *W. A. (& F. K.) Daily* 137, 138, May 3, 1947 (CM, HafR, BU). STARKE COUNTY: 2-6 ft. of

water, Bass Lake, *J. T. Scovell* (3-9), July 12, 1904 (USM, BU); ponds at Bass Lake State Fish Hatchery, *W. A. & F. K. Daily* 121 (CM, HafR, BU), 122 with *C. globularis* (BU), 123 and 124 (CM, HafR, BU), July 6, 1946; in ca. 6 in. of water, Bass Lake, *W. A. & F. K. Daily* 125 with *C. zeylanica* f. *inconstans* (BU), 126 (BU), 127 (CM, HafR, BU), July 6, 1946; 3rd bridge downstream including bridge north of Burr Oak, small swift stream between pond 1 and 2 at dredged Yellow River, *Russell Fisher* 3, July 7, 1946 (BU); old bed of Yellow River, pond 1 (caused by dredging river), 3rd bridge downstream including bridge north of Burr Oak, *Russell Fisher* 5, 6, July 9, 1946 (BU). STEUBEN COUNTY: Shallow water near bank, Bass Lake, *C. M. Palmer* 1068, July 28, 1933 (BU) (basis of the report of *C. fragilis* in Palmer, 28); shallow water in marly border; southeast corner of Pleasant Lake, *R. C. Friesner* 18968, June 15, 1945 (BU); Pigeon River, ½ mi. north of Rd. 20 on County Rd., Sec. 20, ½ mi. east of Otter Lake, *J. E. Potzger* 10380, June 29, 1946 (BU); shallow water, Bass Lake, *W. A. & F. K. Daily* 151 with *C. aspera* var. *Macounii*, Sept. 9, 1947 (CM, BU); Lake James, Pokagon State Park, *Jan Fleming*, *W. A. & F. K. Daily* 152 with *C. aspera* var. *Macounii*, Sept. 9, 1947 (CM, BU); display pond, Pokagon State Park, *W. A. & F. K. Daily* 154 and 157 (CM, HafR, BU), 156 (BU), Sept. 10, 1947; dredged collection, Lake Lonidaw, Pokagon State Park, *W. A. & F. K. Daily* 158, Sept. 10 1947 (BU); Otter Lake, *W. A. & F. K. Daily* 159, Sept. 10, 1947 (CM, HafR, BU); Crooked Creek Pond, Nevada Mills, *W. A. & F. K. Daily* 164 with *C. globularis*, Sept. 11, 1947 (CM, BU); on marly bottom, Snow Lake, north end, off Rd. 120, *W. A. & F. K. Daily* 165, Sept. 11, 1947 (CM, HafR, BU); dredged collection, Circle Park, Hamilton Lake, *W. A. & F. K. Daily* 288A, June 17, 1951 (CM, GOA, BU); Cold Springs Resort, Hamilton Lake, *W. A. & F. K. Daily* 289A, June 17, 1951 (CM, HafR, BU); shallow water, Green Lake, *W. A. & F. K. Daily* 290, June 17, 1951 (CM, BU); dredged collection, southeast corner of Clear Lake, *W. A. & F. K. Daily* 292, June 17, 1951 (CM, GOA, BU); marl pit pond, ca. 2 mi. east of intersection of Rds. 27 and 120 on south side of Rd. 120, ca. 1 mi. from Fremont, *W. A. & F. K. Daily* 295 (CM, BU), 296 (CM, BU), 297 (BU), 299 (CM, BU), 298 on moist soil around pit (BU), June 17, 1951; east shore of Rd. 27 at Pleasant Lake, *W. A. & F. K. Daily* 300 (CM, HafR, BU), 301 (BU), June 18, 1951; Crooked Lake, *W. A. & F. K. Daily*

302 in First Basin, 303 in Third Basin, June 18, 1951 (BU) ; north-west end of Lake Gage, *W. A. & F. K. Daily* 304 with *C. vulgaris*, June 18, 1951 (BU) ; Lime Lake, east side along shore, shallow water, *W. A. & F. K. Daily* 306, 307 with *C. Braunii*, 308, June 18, 1951 (CM, GOA, BU) ; in ca. 2 ft. of water at dam on north side, Nevada Mills, *W. A. & F. K. Daily* 309, June 18, 1951 (BU) ; shallow water, Lake Pleasant, north of Nevada Mills, *W. A. & F. K. Daily* 311 (GOA, BU), 312 (CM, BU), June 18, 1951 ; slightly southeast of Spring Point, Lower Basin, Lake James on southwest side, *W. A. & F. K. Daily* 313 (GOA, BU), 315 with *C. Kieneri* (CM, HafR, GOA, BU), 316 (GOA, BU), June 19, 1951 ; dredged collection, northeast corner Jimerson Lake, *W. A. & F. K. Daily* 322, June 19, 1951 (CM, HafR, BU) ; dredged collection, Lake Lonidaw, Pokagon State Park, *W. A. & F. K. Daily* 326, June 19, 1951 (CM, BU) ; dredged collection, Lake James, Lower Basin, at Potawatomi Inn, *W. A. & F. K. Daily* 327, June 19, 1951 (CM, HafR, BU) ; dredged collection, west side of Fox Lake, southwest of Angola ca. 1.5 mi., *W. A. & F. K. Daily* 328, June 20, 1951 (CM, BU) ; dredged collections, shallow water, Silver Lake, ca. 3 mi. west of Angola on U. S. Rd. 20, *W. A. & F. K. Daily* 330 with *C. aspera* var. *Macounii* (CM, HafR, BU), 331 (BU), 332 (CM, BU), 334B (CM, GOA, BU), 335 with *C. aspera* var. *Macounii* (BU), 336 (BU), 338 with *C. aspera* var. *Macounii* (CM, BU), 339 and 340 (CM, BU), June 20, 1951. VERMILLION COUNTY: Ca. 2 mi. north of Clinton, gravel pit pond, right side of Rd. 63, at C. & E. I. railroad, *W. A. & F. K. Daily* 356 in south lobe of pit, 357 in north lobe of pit, Aug. 28, 1951 (CM, HafR, GOA, BU). VIGO COUNTY: Dredged collection, Greenfield Bayou, 5 mi. southwest of Prarieton, *W. A. & F. K. Daily* 354, Aug. 27, 1951 (CM, HafR, GOA, BU) ; pond, abandoned gravel pit, Crystal Lake, ca. 3 mi. north of Terre Haute on 13th St., *W. A. & F. K. Daily* 355, Aug. 27, 1951 (CM, HafR, GOA, BU). WARREN COUNTY: Elliott's Spring Farm, 3 mi. northwest of Independence, *W. A. & F. K. Daily* 368 in gravel pit pond (CM, HafR, GOA, BU), 369 in artificial pond (GOA, BU), Aug. 31, 1951. WAYNE COUNTY: Shallow water of small sluggish stream, 5 mi. north of Hagerstown, 0.3 mi. along Rd. 1 from junction with Rd. 35, *R. C. Friesner, J. E. Potzger, W. A. & F. K. Daily* 54, Sept. 2, 1944 (BU) ; in shallow water, Clear Creek Swamp, below Earlham College, *Lawrence J. King* 2574, Sept., 1945 (BU) ; near shore of lily

pond, east of pavilion near Lake Wehi, *W. A. & F. K. Daily* 74, June 15, 1945 (CM, HafR, BU); Lake Wehi, *W. A. & F. K. Daily* 75 (CM, HafR, BU), 76 and 77 (BU), June 15, 1946; breeding pond, east of Lake Wehi, *W. A. & F. K. Daily* 81, June 15, 1946 (BU). WELLS COUNTY: Water in limestone quarry, on Rd. 116 north of Bluffton, ca. 2.5 mi., *W. A. & F. K. Daily* 287, June 17, 1951 (CM, HafR, BU). WHITLEY COUNTY: Crooked Lake, *J. T. Scovell* (2-1), probably 1904 (USM, BU); Robinson Lake, *J. T. Scovell* (2-7), (2-8), Sept. 4, 1904 (USM, BU).

For further citation of specimens see *Daily* (7). In that study, collections were reported from Bartholomew, Cass, DeKalb, Elkhart, Fulton, Hancock, Jasper, Johnson, Kosciusko, Lagrange, Lake, Marion, Marshall, Noble, Porter, Putnam, Randolph, Shelby, Steuben, Wayne, and Whitley Counties.

No specimens were seen to support the report in B. H. Smith (40) for Vigo County.

14. *CHARA VULGARIS* Vaill. ex L. *Sp. Pl.*, p. 1156. 1753. (As synonym, *C. foetida* A. Br.)

See *Daily* (6) for description and illustrations under the name *C. foetida*.

A small condensed form found in Indiana bogs and in shallow water is apparently similar to British collections mentioned in Groves and Bullock-Webster (19) as belonging to *C. foetida* var. *condensata* Breb. (*C. coarcta* Wallman) or as arranged in A. Braun's classical treatment—subinermis, macroptila, condensata. Some plants are as small as 4 cm. in height. They have long anterior bracts, somewhat shorter bracteoles, and short spine cells, stipulodes and posterior bract cells. In some collections, there is a tendency to produce entirely ecorticate branchlets in the lower whorls. These branchlets, however, are sterile and not differentiated into nodes and internodes. Because of intergradation in this species, this variety is considered by the author of little taxonomic significance and so is not employed here.

Specimens from Randolph County in *Daily* (7) under the name of *C. foetida* are the bases of the report by Friesner and Potzger (17) for that county.

Specimens seen: CARROLL COUNTY: Bog, between Rd. 25 and Wabash River, 1 mi. northeast of Delphi, *R. C. Friesner* 20356, June 8, 1946 (BU). CASS COUNTY: Springy place on marly flat near northeast corner of Peabody Bog, ca. 3.5 mi. northeast of

Hoovers, *R. C. Friesner* 20602, 20603, June 22, 1946 (BU). HENRY COUNTY: Running water, small stream flowing from springy place in east bank of Blue River Valley, ca. 2.5 mi. north and 1 mi. east of Knightstown, *R. C. Friesner* 22457, Sept. 6, 1948 (BU); by railroad east of Knightstown, Rd. 43, *Johanna Jones*, June 23, 1950 (BU). KOSCIUSKO COUNTY: Dredged collection south side of Carr Lake at Brown's Landing, *W. A. & F. K. Daily* 193 with *C. contraria*, July 22, 1950 (CM, HafR, BU). LAGRANGE COUNTY: Stagnant water near spring, Pigeon River, *Winona H. Welch* 9692, 9693, Aug. 31, 1941 (DU, BU). MARION COUNTY: Pool 24, Riverside Fish Hatcheries, Indianapolis, *Camellia Kenoyer*, *W. A. & F. K. Daily* 129, Sept. 2, 1946 (BU). MARSHALL COUNTY: Maxinkuckee Gun Club and Fish Hatchery, 2 mi. northwest of Culver, *W. A. & F. K. Daily* 92 in drainage ditch from above pond, 93 in pond, July 1, 1946 (CM, HafR, BU); pond with sand and gravel bottom, Old Zeckiel Gravel Pit, near outlet of Lost Lake, *Russell Fisher* 1, July 19, 1946 (BU). PUTNAM COUNTY: 3 mi. south of Greencastle in lake at Limesdale, *Winona H. Welch* 9465, May 17, 1949 (DU, BU). RANDOLPH COUNTY: Gravel excavation along road 0.5 mi. north and 0.7 mi. west of Huntsville, *R. C. Friesner* 19230 in small stream fed by pool, 19231 floating in pool, July 14, 1945 (BU). STARKE COUNTY: Pond caused by dredging Yellow River, third bridge downstream including bridge north of Burr Oak, *Russell Fisher* pkg. 2 with *C. globularis*, July 9, 1946 (BU). STEUBEN COUNTY: Bledsoe's Beach, Lake James, *W. A. & F. K. Daily* 163, Sept. 10, 1947 (BU); marl pit on north side of road ca. 1 mi. from Fremont, ca. 2 mi. from intersection of Rds. 27 and 12, *W. A. & F. K. Daily* 291, June 17, 1951 (CM, HafR, GOA, BU); northwest end, Lake Gage, *W. A. & F. K. Daily* 304, June 18, 1951 (BU); along shore in shallow water, east side of Lime Lake, *W. A. & F. K. Daily* 305, June 18, 1951 (CM, HafR, GOA, BU). WAYNE COUNTY: Very dense growth in shallow water, Clear Creek, *Lawrence J. King* 2575, Sept., 1945 (EC, CM, BU).

For further citation of specimens see *Daily* (7) under the name, *C. foetida* A. Br. In that study, specimens were reported from Carroll, Kosciusko, LaGrange, Lake, Randolph, St. Joseph, Tippecanoe and Wayne Counties.

No specimens were seen to support the report of Evermann and Clark (15) under the name of *C. foetida* and *C. vulgaris* from Lake

Maxinkuckee, Marshall County. The only reference to distribution in Lake Maxinkuckee is, "Represented in our collection by numerous examples." At least some of the material was not fruiting and may not have been preserved for this reason. Evermann and Clark's report of *C. vulgaris* was also cited by Palmer (27).

15. *CHARA GLOBULARIS* Thuill. Flor. Env. Paris, ed. 2, p. 472. 1799. (As synonym, *C. fragilis* Desv.)

See *Chara fragilis* in Daily (6) for general description and illustrations. In Indiana specimens the ridges on the oospores range from 9-15. The oospores are ca. 480-690 μ long and dark brown to black.

Included here are: the specimen probably referred to by genus name only in Evermann and Clark (13) and also cited by Palmer (29) from Lake Cicott, Cass County; possibly the specimens to support the report of *C. fragilis* from Long Point near Scovell's and "occasional in the lake," Lake Maxinkuckee, Marshall County, reported by Evermann and Clark (15) whose study was also cited by Palmer (27); also probably some of the specimens referred to by genus name only in Scovell (39) for Treighbaum and Pretty Lakes in Marshall County.

Specimens seen: BARTHOLOMEW COUNTY: Pond at overpass on Rd. 31 ca. 2.5 mi. north of Columbus, *W. A. & F. K. Daily* 62 (CM, BU), 63 (BU), 64 with *C. contraria* (CM, BU), 67 with *C. contraria* (CM, HafR, BU), 68 with *C. contraria* (CM, BU), 69 (CM, BU), 70 and 72 with *C. contraria* (CM, HafR, BU), 71 with *C. contraria* (CM, BU), July 12, 1945, 130 (CM, HafR, BU), Apr. 20, 1947; pond at overpass on Rd. 31, ca. 2.5 mi. north of Columbus, *Mary Fritsche Cundiff, W. A. & F. K. Daily* 173, May 13, 1949 (CM, BU). CASS COUNTY: Lake Cicott near Logansport, *B. W. Evermann* 1581 (616), Oct. 20, 1900 (USM, BU) (Probably the basis for the report of *Chara* from Lake Cicott by Evermann and Clark, 13, and also cited by Palmer, 29). CLAY COUNTY: Strip mine pond, ca. 2 or 3 mi. south of Brazil on the west side of Rd. 59, *Florence Geisler, Francis Hueber, W. A. & F. K. Daily* 276, Sept. 16, 1950 (CM, HafR, BU); pond, Big Ben Collieries, west side of Rd. 59, south of Ashboro, *Florence Geisler, F. Hueber, W. A. & F. K. Daily* 278, Sept. 23, 1950 (CM, HafR, BU); pond, strip mine, 1 mi. north of intersection of State Rd. 46 and 59, *Florence Geisler, F. Hueber, W. A. & F. K. Daily* 281 (BU), 282 (CM, BU), Sept. 23,

1950. DECATUR COUNTY: Pond north side of railroad track near Allen Lake, off Rd. 46 and 3, *W. A. & F. K. Daily* 57, Oct. 10, 1944 (BU). HAMILTON COUNTY: Stagnant pond, northeast end of Geist Reservoir, *Johanna Jones* 1403, 1405, Aug. 12, 1951 (BU). HARRISON COUNTY: Pond ca. 6½ mi. east of Corydon on Rd. 62, *C. M. Palmer*, *W. A. & F. K. Daily* 142, May 10, 1947 (CM, HafR, BU). HENDRICKS COUNTY: Shallow water, Penn Lake, 3 mi. east of Brownsburg, *W. A. & F. K. Daily* 261, Aug. 2, 1950 (CM, BU). JACKSON COUNTY: Along shore in shallow water, Starve Hollow Lake, Driftwood State Fish Hatchery, near Valonia, *W. A. & F. K. Daily* 265 with *C. sejuncta*, Aug. 26, 1950 (CM, HafR, BU). JAY COUNTY: Large pond, on overpass southwest of Red Key on Rd. 67, *W. A. & F. K. Daily* 286 with *C. contraria*, June 16, 1951 (CM, HafR, BU). KOSCIUSKO COUNTY: 4-8 ft. of water, Tippecanoe Lake, *J. T. Scovell* (3-18) with *C. contraria*, July 25, 1904 (USM, BU); Dewart Lake, *W. A. & F. K. Daily* 177 with *C. contraria* (CM, BU), 179 with *C. contraria* (CM, HafR, BU), 180 with *C. aspera* var. *Macounii* (BU), 181 and 182 (CM, HafR, BU), July 9, 1949; Dewart Lake, *W. A. & F. K. Daily* 184 (CM, HafR, BU), 186 (CM, BU), 187 with *C. excelsa* (CM, BU), 188 (BU), 189 (CM, BU), 190 with *C. contraria* (BU), July 10, 1949; in shallow water, Lake Wawasee, Johnson's Hotel at pier, *W. A. & F. K. Daily* 197, July 23, 1950 (CM, HafR, BU); Lake Wawasee, behind Johnson's Hotel Annex, *W. A. & F. K. Daily* 201 with *C. aspera* var. *Macounii* (CM, HafR, BU), 204 and 209 with *C. contraria* (CM, HafR, BU), 205 with *C. contraria* (CM, HafR, BU), 208 with *C. contraria* (CM, BU), July 23, 1950; dredged collection, Syracuse Lake, Syracuse City Park Pier, *W. A. & F. K. Daily* 212 with *C. contraria*, July 23, 1950 (CM, HafR, BU); pond, Wawasee State Fish Hatchery, *W. A. & F. K. Daily* 214 with *C. contraria*, July 23, 1950 (CM, BU); dredged collection, channel between Lake Wawasee and Lake Syracuse, *W. A. & F. K. Daily* 218 (CM, BU), 219 with *C. contraria* (CM, HafR, BU), July 24, 1950; dredged collections, Sturm and Dillard gravel pit pond, near B. & O. railroad tracks, 2.5 mi. west of Syracuse, *W. A. & F. K. Daily* 220 with *C. contraria* (CM, HafR, BU), 220A (CM, BU), 222 with *C. contraria* (BU), July 24, 1950; in shallow water, Lake Wawasee, west of Johnson's Hotel, *W. A. & F. K. Daily* 233 with *C. contraria* (CM, HafR, BU), 235 with *C. contraria* (CM, BU), July 26, 1950;

in shallow water, east of Johnson's Hotel at Turkey Creek Inlet, Lake Wawasee, *W. A. & F. K. Daily* 240 with *C. contraria*, July 26, 1950 (CM, HafR, BU) ; Durham Lake (Daniel's Lake) several mi. south-east of North Webster, *W. A. & F. K. Daily* 243 with *C. zeylanica* f. *Humboldtiana* (BU), 244 (CM, BU), July 27, 1950 ; dredged collection, Lake Papakeechee, *F. K. Daily* 251 with *C. contraria*, July 28, 1950 (CM, HafR, BU). LAWRENCE COUNTY: Second pond from station toward road, Avoca State Fish Hatchery, *W. A. & F. K. Daily* 253 with *C. Kieneri*, Aug. 1, 1950 (CM, HafR, BU). MARION COUNTY: Pond west of Bridgeport ca. $\frac{1}{2}$ mi., north side of Rd. 40, *W. A. & F. K. Daily* 344, Aug. 25, 1951 (CM, GOA, BU). MARSHALL COUNTY: Probably *C. fragilis*, in front of Scovell's house on Long Point, Lake Maxinkuckee, *J. T. Scovell* 1570, July 17, 1900 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer, 27) ; grew in the laboratory of J. T. Scovell from Sept. 1903 to Sept. 1904, originally from Lake Maxinkuckee, *J. T. Scovell* (2-11) with *C. contraria*, Sept., 1903 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and C. M. Palmer, 27) ; ca. 3 ft. of water, Myers Lake, *J. T. Scovell* (3-6) with *C. contraria*, July 7, 1904 (USM, BU) ; 3-6 ft. of water, Treighbaum Lake, *J. T. Scovell* (3-10) with *C. contraria*, July 8, 1904 (USM, BU) (Probably the basis of the report of Chara by Scovell, 39) ; Pretty Lake, *J. T. Scovell* (3-14, 3-14x, 3-14xx), July 21, 1904 (USM, BU) (Probably the basis of the report in Scovell, 39) ; 11 ft. of water, on south end of lake bar, north of Maxinkuckee line, Lake Maxinkuckee, *J. T. Scovell* (3-21) with *C. contraria*, July 30, 1904 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer, 27) ; 8 ft. of water, dark marl mud, west side of Long Point Bar, on the Maxinkuckee line, Lake Maxinkuckee, *J. T. Scovell* (3-22) with *C. contraria*, July 30, 1904 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer, 27) ; 6-8 ft. of water, Lake Maxinkuckee, *J. T. Scovell* (3-20A) with *C. contraria*, Aug. 2, 1904 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer, 27) ; ponds, Maxinkuckee Gun Club and Fish Hatchery, 2 mi. northwest of Culver off State Rd. 10, *W. A. & F. K. Daily* 90 and 94 with *C. contraria*, July 1, 1946 (CM, HafR, BU) ; shallow water, Lost Lake (Hawk's Pond), *W. A. & F. K. Daily* 99 and 104 with *C. contraria* (CM, HafR, BU), 107 with *C. contraria* (CM, HafR, BU),

100 with *C. contraria* (CM, BU), 101 (BU), 105 (CM, BU), July 3, 1946; shallow water, Farrar's Woods, Lake Maxinkuckee, *W. A. & F. K. Daily* 113, July 4, 1946 (CM, HafR, BU); shallow water, Rossa's Pier, Lake Maxinkuckee, *W. A. & F. K. Daily* 116 (CM, HafR, BU), 117 with *C. contraria* (BU), July 5, 1946; mud bottom, water ca. knee deep, water plants growing densely, Lake Maxinkuckee Outlet, *Russell Fisher*, *W. A. & F. K. Daily* 118 with *C. contraria*, July 5, 1946 (CM, HafR, BU); Lost Lake, *Russell Fisher B* with *C. sejuncta*, *C.*, July 8, 1946 (BU). MIAMI COUNTY: Gravel pit pond, J. C. O'Connor General Contractors, on south side of U. S. Rd. 24, ca. 6 mi. west of Rich Valley, *W. A. & F. K. Daily* 191, July 22, 1950 (CM, HafR, BU). NEWTON COUNTY: Shallow pools at edge of gravel pit pond, ca. 3 mi. north of Ade, right side of first road west and paralleling Rd. 41, *W. A. & F. K. Daily* 358 with *C. Kieneri*, Aug. 28, 1951 (BU); gravel pit pond, dredged collection, ca. 3 mi. north of Ade, right side of first road west and paralleling Rd. 41, *W. A. & F. K. Daily* 359, Aug. 28, 1951 (CM, HafR, GOA, BU). NOBLE COUNTY: Tippecanoe (Big Lake), *J. T. Scovell* (2-10), Sept. 3 and 4, yr.? (USM, BU). OWEN COUNTY: Old limestone quarry pond, McCormick's Creek State Park, *Al Jose*, *W. A. & F. K. Daily* 145, Aug. 9, 1947, *W. A. & F. K. Daily* 284, May 5, 1951 (CM, HafR, BU). PARKE COUNTY: Pond, Rd. 41 south of railroad bridge, near Turkey Run State Park, *Sidney R. Esten*, *W. A. & F. K. Daily* 146, 147, Aug. 16, 1947 (CM, HafR, BU). PUTNAM COUNTY: Lake at Limesdale, 3 mi. south of Greencastle, *Winona Welch* 9465 with *C. vulgaris*, May 17, 1949 (DU, BU); Lone Star Cement Co., 2 mi. south of Greencastle, *W. A. & F. K. Daily* 262 from limestone quarry pond, 263 from shallow pool caused by quarry pond overflow and recession, Aug. 2, 1950 (CM, HafR, BU). STARKE COUNTY: 2-6 ft. of water, Bass Lake, *J. T. Scovell* (3-9) with *C. contraria*, July 12, 1904 (USM, BU); pond, Bass Lake State Fish Hatchery, *W. A. & F. K. Daily* 122 (BU), 124 with *C. contraria* (CM, HafR, BU), July 6, 1946; pond caused by dredging Yellow River, third bridge downstream including bridge north of Burr Oak, *Russell Fisher pkg. 2*, July 9, 1946 (BU). STEUBEN COUNTY: Bledsoe's Beach, Lake James, *W. A. & F. K. Daily* 163 with *C. vulgaris*, Sept. 10, 1947 (BU); Crooked Creek pond, Nevada Mills, *W. A. & F. K. Daily* 164, Sept. 11, 1947 (CM, BU); dredged collection Hamilton Lake,

Circle Park, *W. A. & F. K. Daily* 288B with *C. Kieneri*, June 16, 1951 (GOA, BU) ; east side of Mirror Lake, *W. A. & F. K. Daily* 294, June 17, 1951 (CM, BU) ; slightly southeast of Spring Point, Lower Basin, Lakes James on southwest side, *W. A. & F. K. Daily* 313 with *C. contraria*, June 19, 1951 (GOA, BU) ; Lake James, Lower Basin, Potawatomi Inn, Pokagon State Park, *W. A. & F. K. Daily* 327 with *C. contraria*, June 19, 1951 (CM, HafR, BU) ; dredged collections, shallow water, Silver Lake, ca. 3 mi. west of Angola on Rd. 20, *W. A. & F. K. Daily* 331 with *C. contraria* (BU), 332 with *C. contraria* (CM, BU), 338 with *C. aspera* var. *Macounii* (CM, BU), June 20, 1951. SULLIVAN COUNTY: With *C. sejuncta*, Shakamak Lake, Shakamak State Park, *Florence Geisler*, Sept. 30, 1951 (BU). VIGO COUNTY: Strip mine pond, ca. 1 mi. northeast of Riley, off State Rd. 46 on southwest side of road, across railroad track on small dirt road, Maumee Collieries, *W. A. & F. K. Daily* 353, Aug. 26, 1951 (CM, HafR, GOA, BU). WAYNE COUNTY: Dredged collection, lily pond east of pavilion near Lake Wehi, *W. A. & F. K. Daily* 73, 74 with *C. contraria*, June 15, 1946 (CM, HafR, BU) ; Lake Wehi, *W. A. & F. K. Daily* 75 with *C. contraria* (CM, HafR, BU), 80 (BU), June 15, 1946. WELLS COUNTY: Infrequent because pond contiguous with farm lot, old gravel pit at least 40 years old, northeast quarter of Sec. 31, ca. 1¼ mi. northeast of Poneto, *C. C. Deam* 63148, Oct. 14, 1944 (BU).

For further citation of specimens see *Daily* (7) under the name of *Chara fragilis* Desv. In that study, specimens were reported from Bartholomew, Decatur, Hamilton, Marion, Noble, Shelby, Steuben, Union and Wayne Counties.

No specimens were seen to support the report in Smith (40) for Clay County or Palmer (28) for bog near Hogback Lake in Steuben County.

16. *CHARA ZEYLANICA* Willd. *Mem. Acad. Roy. Sc. Berlin*, pro anno 1803, p. 86. 1805. Berlin.

Habit flexible to rigid ; upper stem internodes shorter than branchlets ; lower whorls remote, ca. 10-14 branchlets in a whorl ; branchlets with 6-13 nodes ; monoecious ; stem cortex regularly triplostichous, cells about equal in diameter ; spine cells borne singly, long ; stipulodes in two series, long, slender, sharply pointed, variable in length ; lowest branchlet internode ecorticate, variable in length ; next lowest branchlet internode triplostichous (or as in f. *inconstans* some

branchlets may be entirely ecorticate) first branchlet node may or may not be fertile; number of branchlet internodes corticated variable; bracts and bracteoles quite variable (in f. *Humboldtiana* rather long, in f. *Michauxii* short); oospores usually having 13 or 14 ridges, ca. 525-735 μ long, black; oospore membrane dark brown with granules; antheridia ca. 370-480 μ in diameter.

See Daily (6) for illustrations.

KEY TO THE FORMS FOUND IN INDIANA

Lowest node of the branchlet usually fertile, bracts similar to the others

Branchlet nodes 8-10, oospore ca. 580-689 μ long, all branchlets with at least some internodes corticated.....

.....f. *macilenta*

Branchlet nodes 6-7, oospore ca. 525 μ long, at least some of branchlets entirely ecorticate, particularly

those of the lowest stem nodes.....f. *inconstans*

Lowest node of the branchlet usually sterile, bracts similar to the others

Branchlet nodes 10-12, oospore ca. 636-689 μ long, plant large, bracts particularly at sterile nodes very minute

.....f. *Michauxii*

Branchlet nodes 12 or 13, oospore ca. 700-735 μ long, bracts

longer than in f. *Michauxii*.....f. *Humboldtiana*

CHARA ZEYLANICA f. *MACILENTA* nov. comb. (As synonym for *Chara gymnopus* var. *macilenta* A. Br. ex Braun and Nordstedt. *Fragmente Einer Monographie der Characeen*. Abh. Kön. Akad. Berlin, 1882, p. 192, Taf. VII, Fig. 271. 1883).

Included here are the specimens probably the basis of the report by Evermann and Clark (15) under the general heading *Chara foliolosa* Muhlenberg and Willdenow, "On the shore of Lake Maxinkuckee on the west side by Winfield's." Farther along in this same treatment, they state, "Various modifications or subspecies of this form, such as *Chara foliolosa macilenta*, . . ., are to be found along the shores of Lost Lake." The general heading *Chara foliolosa* was also cited by Palmer (27).

Included here also is a specimen probably the basis of the report by genus name only in H. W. Clark (5) and C. M. Palmer (27) for Winona (Eagle) Lake, Kosciusko County.

Specimens seen: KOSCIUSKO COUNTY: In shallow water, Winona Lake (Eagle), *H. W. Clark* and *B. W. Evermann* 17, Aug. 25, 1906 (CM, USM, BU) (Probably the basis of the report of *Chara* in Clark, 5, which was cited also by Palmer, 27). MARSHALL COUNTY: Not particularly common on muddy bottom, south end of Lost Lake, *B. W. Evermann* 1573 (569), Sept. 16, 1900 (USM, BU) (Probably the basis of the report in Evermann and Clark, 15, and Palmer, 27); in muddy bottom, north end of Lost Lake, *B. W. Evermann* 1577 (579), Sept., 1900 (USM, BU) (Probably the basis for the report in Evermann and Clark, 15, and Palmer, 27); Outlet Bay near Winfield's, Lake Maxinkuckee, *H. W. Clark* 16, Nov. 15, 1904 (USM, BU) (Probably the basis for reports in Evermann and Clark, 15, and Palmer, 27). STEUBEN COUNTY: Shallow water at shore, Lake James, *Jan Fleming*, *W. A. & F. K. Daily* 153, Sept. 9, 1947 (CM, HafR, BU); in a few in. of water, Green Lake, *W. A. & F. K. Daily* 161, Sept. 10, 1947 (BU).

For further citation of specimens, see *Chara gymnopus* in Daily (7). In that study, the specimens reported for Cass and Lake Counties belong to this form.

CHARA ZEYLANICA f. INCONSTANS (Kütz.) H. & J. Groves. In Ignatius Urban. *Symbolae Antillanae seu Fundamenta Florae Indiae Occidentalis* 7 (1): 41. Berolini. 1911.

Specimen seen: STARKE COUNTY: In ca. 6 in. of water, Bass Lake, *W. A. & F. K. Daily* 125, July 6, 1946 (BU).

CHARA ZEYLANICA f. MICHAUXII (A. Br.) H. & J. Groves. In Ignatius Urban. *Symbolae Antillanae seu Fundamenta Florae Indiae Occidentalis* 7(1): 42. Berolini. 1911.

Included here are the specimens probably the basis for the report by genus name only in the manuscript on Twin Lakes, Marshall County, by J. T. Scovell (39).

Specimens seen: CLAY COUNTY: Dredged collection, strip mine pond, Big Bend Collieries on east side of State Rd. 59 south of Ashboro, *F. Geisler*, *F. Hueber*, *W. A. & F. K. Daily* 279, Sept. 23, 1950 (CM, HafR, BU); dredged collection from a strip mine pond, ca. $\frac{1}{4}$ mi. east of junction of State Rds. 59 and 42 on south side of Rd. 42, *W. A. & F. K. Daily* 349, Aug. 26, 1951 (CM, HafR, GOA, BU). HARRISON COUNTY: Pond in old rock quarry, on south side of Rd. 62 ca. $2\frac{1}{2}$ mi. east of Corydon, *C. C. Deam* 63504, 63507, Aug. 22, 1945 (BU); shallow water in old limestone quarry, along

Rd. 62, 1.9 mi. east of Corydon, R. C. Friesner 19559, Sept. 1, 1945 (BU). KOSCIUSKO COUNTY: Ridinger Lake, J. T. Scovell (2-4) with *C. contraria*, (2-6), Sept. 4, 1904 (USM, BU); shallow water of an excavated channel, southeast side of Chapman Lake, R. C. Friesner 23166, Sept. 24, 1949 (BU); shallow water, Winona Lake, W. A. & F. K. Daily 196, July 23, 1950 (CM, BU); dredged collection from water in Sturm and Dillard Gravel Pit, 2.5 mi. west of Syracuse, W. A. & F. K. Daily 220A with *C. globularis*, July 24, 1950 (CM, BU); dredged collection from Upper Tippecanoe (James Lake), W. A. & F. K. Daily 231 with *C. contraria*, July 25, 1950 (CM, HafR, BU); shallow water of Lake Wawasee, west of Johnson's Hotel, W. A. & F. K. Daily 235 with *C. contraria*, July 26, 1950 (CM, BU); dredged collection, Ridinger Lake, W. A. & F. K. Daily 247, July 27, 1950 (CM, HafR, BU). MARSHALL COUNTY: 6-8 ft. of water, Pretty Lake, J. T. Scovell (3-13), July 21, 1904 (USM, BU) (Probably the basis of the report of Chara in Scovell, 39); Pretty Lake, J. T. Scovell (3-14, 3-14x, 3-14xx) with *C. globularis*, July 21, 1904 (USM, BU) (Probably the basis of the report of Chara in Scovell, 39). NOBLE COUNTY: Tippecanoe (Big Lake), J. T. Scovell (2-10) with *C. globularis*, Sept. 3 & 4, year? (USM, BU); Skinner Lake, W. A. & F. K. Daily 148 (BU), 149 (CM, HafR, BU), Sept. 9, 1947.

For further citation of specimens see *Chara gymnopus* in Daily (7). In that study, specimens reported from Jefferson, Noble and Whitley Counties belong to this form.

CHARA ZEYLANICA f. HUMBOLDTIANA (A. Br.) Zaneveld. Some Notes on Charophyta Collected in the Netherlands, West Indies, North Venezuela and Colombia. Nederl. Bot. Vereen., Rec. Trav. Bot. Neerl. 38: 145. 1942.

Specimen seen: KOSCIUSKO COUNTY: Durham Lake (Daniel's Lake) several mi. southeast of North Webster, W. A. & F. K. Daily 243, July 27, 1950 (BU).

For further citation of specimens, see *Chara gymnopus* A. Br. in Daily (7). In that study specimens reported from Bartholomew County belong to this form.

No specimens were seen to support the following reports: *C. polyphylla* from Wabash River, Gibson County, reported by J. Schneck (35) and C. M. Palmer (27); *C. foliolosa*, "alcoholic specimen in bottle marked Sp. 4" and "extending from Long Point down to about

Farrar's," reported from Marshall County by B. W. Evermann and H. W. Clark (15); *C. foliolosa conjugens* from Lost Lake, Marshall County, reported by B. W. Evermann and H. W. Clark (15).

17. CHARA SEJUNCTA A. Br. Plantae Lindheimerianae. Boston Jour. Nat. Hist. 5: 264 (foot-note). 1845.

For general description and illustrations see Daily (6). In Indiana specimens the oospores are 735-848 μ long, 500-636 μ wide with 11 or 12 ridges; antheridia ca. 370 μ in diameter.

Specimens seen: BROWN COUNTY: Dredged collection, Jimmy Strahl Lake, Brown County State Park, *Mary Fritzsche, W. A. & F. K. Daily 166 and 167* (CM, HafR, BU), 169 (BU), *W. A. (& F. K.) Daily 171* (BU), Sept. 19, 1947. CLAY COUNTY: Near shore in a few in. of water, Zenor Pit, 1½ mi. southeast of Center Point, *W. A. & F. K. Daily 352B*, Aug. 26, 1951 (CM, GOA, BU). DUBOIS COUNTY: Shallow water, New Lake (City Water Co. Lake), Huntingburg, *W. A. & F. K. Daily 256*, Aug. 2, 1950 (CM, HafR, BU); shallow water, Old City Lake, Huntingburg, *W. A. & F. K. Daily 257*, Aug. 2, 1950 (BU); dredged collection, Ferdinand Lake, Ferdinand State Forest, *W. A. & F. K. Daily 258*, Aug. 2, 1950 (CM, HafR, BU). JACKSON COUNTY: Ca. 2 ft. of water, Starve Hollow Lake, Driftwood State Fish Hatchery near Valonia, *W. A. & F. K. Daily 264* (CM, BU), 265 (CM, HafR, BU), 266 (BU), Aug. 26, 1950. JENNINGS COUNTY: Grayford Pond, *W. A. & F. K. Daily 275*, Sept. 16, 1950 (CM, BU). MARSHALL COUNTY: Lost Lake, *Russell Fisher B*, July 8, 1946 (BU). MONROE COUNTY: Bean Blossom Lake, Morgan-Monroe State Forest, *Robert Prettyman*, Oct. 14, 1944 (BU). ORANGE COUNTY: Shallow pond, 3 mi. east of Orlean, *W. A. & F. K. Daily 259*, Aug. 2, 1950 (CM, HafR, BU); shallow water, City Water Works, Lake Orlean, *W. A. & F. K. Daily 260*, Aug. 2, 1950 (CM, BU). PARKE COUNTY: In shallow water at shore, Lena Lake, ½ mi. east of Lena, *W. A. & F. K. Daily 345*, Aug. 25, 1951 (CM, HafR, GOA, BU); dredged collection, Thomas Lake, 1½ mi. east of Lena, *W. A. & F. K. Daily 346* (CM, GOA, BU), 347 and 348 (GOA, BU), Aug. 25, 1951. PORTER COUNTY: Dredged collection, Long Lake, ca. 1 mi. southwest of Wauhob Lake near Valparaiso, *W. A. & F. K. Daily 367*, Aug. 30, 1951 (CM, HafR, GOA, BU). SULLIVAN COUNTY: Shakamak Lake, Shakamak State Park, *Florence Geisler*, Sept. 30, 1951 (BU). WASHING-

TON COUNTY: In sinkhole on south side of Rd. 56, ca. $4\frac{1}{2}$ mi. southwest of Salem, C. C. Deam 63468, Aug. 21, 1945 (BU).

For further citation of specimens see Daily (7). In that study, collections were reported from Porter, Spencer, Steuben and Sullivan Counties.

18. *CHARA DELICATULA* Ag. Syst. Alg., p. 130. 1824. (non Desv.) (As synonym, *C. verrucosa* Itzig.)

For general description and illustrations see Daily (6) under *Chara verrucosa*. Indiana specimens have: upper series of stipulodes variable in size, lower slightly developed; coronula of oogonium connivent; oospores ca. 635-685 μ in length, 400-480 μ broad with 12-14 ridges; antheridia ca. 420-470 μ in diameter.

Included here is a specimen probably the basis of the report of *Chara subverrucosa* A. Br. by Evermann and Clark (15) and also cited by Palmer (27) from Lake Maxinkuckee, Marshall County. The report by Evermann and Clark states that it is "occasional in the lake, represented in the collection by several specimens." Only one was seen. It is difficult to classify this specimen as the prominence of the primary cortical cells is variable; however, the author believes it belongs here.

Specimens seen: MARSHALL COUNTY: Lake Maxinkuckee, J. T. Scovell (3-20A) with *C. contraria*, Aug. 2, 1904 (USM, BU) (Probably the basis for the report of *C. subverrucosa* in Evermann and Clark, 15, whose study was also cited by Palmer, 27); shallow water, muck bottom, Old Outlet Bed, Lake Maxinkuckee, Russell Fisher, July 8, 1946 (BU). NOBLE COUNTY: Tippecanoe (Big Lake), J. T. Scovell (2-9), Sept. 3, 1904 (USM, BU). PORTER COUNTY: Dredged collection, Moss Lake, $\frac{1}{2}$ mi. west of Lake Wauhob near Valparaiso, W. A. & F. K. Daily 363 with *Nitella* (BU), 364 (CM, HafR, GOA, BU), Aug. 30, 1951.

For further citation of specimens see Daily (7) under the name *Chara verrucosa*. In that study, one specimen was reported from Noble County.

19. *CHARA ASPERA* Willd. Ges. Naturf. Fr. Berlin Mag. 3: 298. 1809.

Habit small, not over 30 cm. in height (var. *Macounii* usually only a few centimeters in height), slender, producing bulbils at the rhizoidal portion; dioecious; branchlets usually 6-8 at a node having 5-8 segments, the lower ones diplostichous, the upper 1 or 2 ecorticate and usually short; stem cortex irregularly triplostichous, appearing

at times diplostichous because secondary cells developed in one direction or developed only a short distance in both directions from a node, cells variable in diameter, primary usually prominent; spine cells papilliform and blunt to ca. 200 μ long and pointed; stipulodes in 2 series in a circle around the stem, usually well developed but variable even at the same stem node; bracteoles and bracts variable in size; oospore black with 12-15 ridges, usually 400-650 μ long; antheridia ca. 500 μ in diameter.

CHARA ASPERA var. *MACOUNII* Allen. Bul. Torrey Bot. Club. 9: 44. 1882.

For illustrations see Daily (6) under *Chara aspera*.

The present collections of this species from Indiana are probably all referable to this variety, which differs from the type chiefly by its relatively small stature and in having stipulodes and spine cells reduced in size.

As the type material was immature, the number of ridges of the oospore is usually given as probably 8-10. The author saw no oospores in the type material which could be used as a basis for size or number of ridges with certainty. Ripe oospores are usually apparently scarce in collections as is the case in Indiana. From the immature material at hand, though, it would appear that oospores would at least have as many as 12-13 ridges. A specimen from Nebraska otherwise referable to this variety had 13 ridges, was black and appeared to be similar to the oospore usual for the species. (Fish ponds, Rock Creek Hatchery, Dundy County, Nebraska, *Walter Kiener 19510*, Aug. 3, 1945).

Included here are the specimens which are probably the bases of the report of *Chara* by J. T. Scovell (39) for Pretty Lake, Marshall County.

Specimens seen: KOSCIUSKO COUNTY: Shallow water, James Lake (part of Tippecanoe Lake system), *J. T. Scovell* (3-7), June 25, 1904 (USM, BU); Dewart Lake, *W. A. & F. K. Daily* 176 and 177 with *C. contraria* (CM, BU), 180 (BU), 183 with *C. contraria* (CM, BU), July 9, 1949; behind Johnson's Hotel Annex in inlet, Lake Wawasee *W. A. & F. K. Daily* 201, 205 with *C. contraria*, July 23, 1950 (CM, HafR, BU); dredged collection, Syracuse Lake, Syracuse City Park Pier, *W. A. & F. K. Daily* 213 with *C. contraria*, July 23, 1950 (CM, HafR, BU); dredged collection from Upper Tippecanoe (Little Tippecanoe, James Lake), *W. A. & F. K. Daily*

228 with *C. contraria*, July 25, 1950 (CM, HafR, BU) ; in shallow water, Lake Wawasee, west of Johnson's Hotel, *W. A. & F. K. Daily* 232, July 26, 1950, (CM, HafR, BU) ; Kuhn Lake, *W. A. & F. K. Daily* 246, July 27, 1950 (CM, HafR, BU). MARSHALL COUNTY: Pretty Lake, *J. T. Scovell* (3-14, 3-14x, 3-14xx) with *C. globularis*, July 21, 1904 (USM, BU) (probably the basis for the report in Scovell, 39) ; in shallow water ca. 3 ft. deep, Long Point, Lake Maxinkuckee, *W. A. & F. K. Daily* 97, July 2, 1946 (CM, HafR, BU) ; dredged collection, in ca. 3 ft. of water, Lost Lake (Hawk's Pond), *W. A. & F. K. Daily* 98, 105 with *C. globularis*, July 3, 1946 (CM, BU) ; shallow water, Farrar's Woods, Lake Maxinkuckee, *W. A. & F. K. Daily* 114, July 4, 1946 (CM, BU). STEUBEN COUNTY: Shallow water, Bass Lake, *W. A. & F. K. Daily* 151, Sept. 9, 1947 (CM, BU) ; dredged collection, Lake James, Pokagon State Park, *Jan Fleming*, *W. A. & F. K. Daily* 152, Sept. 9, 1947 (CM, BU) ; shallow water, southwest end of Long Lake, northeast part of Steuben County, *W. A. & F. K. Daily* 293, June 17, 1951 (CM, HafR, BU) ; in shallow water, Lake Pleasant, north of Nevada Mills, *W. A. & F. K. Daily* 310, June 18, 1951 (CM, HafR, GOA, BU) ; shallow water, east of bridge over canal between Middle Basin of Lake James and Jimerson Lake, *W. A. & F. K. Daily* 319, June 19, 1951 (CM, GOA, BU) ; Fox Lake, southwest of Angola in the southwest part of Steuben County, *W. A. & F. K. Daily* 329, June 20, 1951 (CM, HafR, BU) ; shallow water, Silver Lake, ca. 3 mi. west of Angola on U. S. 20, *W. A. & F. K. Daily* 330 (CM, HafR, BU) 331 with *C. contraria* (BU), 334B with *C. contraria* (CM, GOA, BU), 335 (BU), 338 (CM, BU), June 20, 1951.

For further citation of specimens see Daily (7). In that study, a specimen was reported for Kosciusko County.

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SECONDARY SUCCESSION IN STANDS OF RED MAPLE—SWEET GUM—BEECH FORESTS IN RIPLEY COUNTY, INDIANA*

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The vegetation of the leached Illinoian till plain has been described in detail by Braun (1, 2) Keller (4), McCoy (5), and the progress of secondary succession in these habitats has been considered quantitatively by Potzger and Potzger (7), and in a more general way by Chapman (3). Realizing the insecure accuracy of empirical field impressions, the present quantitative study of seven stands on Illinoian till plain forests in the process of developing either from lumbering disturbance or from cleared land was undertaken.

METHODS

Stands selected have not been disturbed by grazing, so it can be assumed that reproduction followed a natural course. In all but the Reinking woods (table 1) twenty 10-meter-square quadrats were delimited by synthetic wash line with loops at ten meter intervals which could easily be slipped over wire stakes. Wooden calipers were used to make DBH. measurements of trunks. Young trees, at least three feet in height and below one inch DBH. were tabulated as index for reproduction.

LOCATION AND DESCRIPTION OF THE STANDS

Reinking woods: 55.59 A. Lumbered but not cleared, undisturbed for 36 years. It is located along highway 421 near Osgood.

Huneke woods (table 2) 8.43 A. Lumbered, not cleared. Undisturbed for 25 years.

Clyde Peetz woods (table 3) 11.1 A. Lumbered, not cleared. Undisturbed for 20 years.

Ben Fangman woods (table 4). Completely cleared but not farmed. Undisturbed for 30 years.

* This is publication 270 from the Botany Laboratory of Butler University and paper 5 of the Purdue Conservation Camp faculty.

Eldon Ehlers south woods (table 5) 15 A. Cleared but not farmed. Undisturbed for 23 years.

Eldon Ehlers north woods (table 6) about 15 A. Cleared, not farmed. Undisturbed for 27 years.

Versailles Park (table 7) about 10 A. Cleared and farmed. Undisturbed for 15 years.

All of the stands are located within a few miles of Versailles and Osgood.

RESULTS

The youth of all stands is indicated by small DBH. of trunks. The youngest is, of course, the Versailles Park stand (table 7). The number of dominant trees is larger and their per cent F. I. higher than in forests of more mesophytic habitats. In abundance and F. I. *Acer rubrum*, Liquidambar and *Ulmus americana* are leading all other genera. In succession following lumbering number of stems per quadrat is smaller and average diameter of stems is greater than in stands which began on cleared areas. This indicates greater progress in succession with reduced disturbance. Succession in the strictest ecological sense, i. e. by a succession of seres, is not evident in these Illinoian till plain forests. This can readily be seen from tables 1 to 7.

DISCUSSION

In habitats of the Illinoian till plain microclimate plays an important role in invasion by various species especially of *Acer saccharum*, and perhaps also has marked influence on the invasion by *Liriodendron* and others. This was pointed out by Chapman (3) when he says, "The species composition of the stand varied with drainage conditions." In the Versailles-Osgood area variation is apparently not sufficiently great to disturb the forest type but only to make variation in abundance of one or the other species. Potzger (6) pointed out that drainage by a few feet of cutting by a little stream in the Versailles Park region eliminated Liquidambar and *Acer rubrum* from the association and gave the climax beech-sugar maple-ash association control.

The authors agree with Chapman (3) that the forest type is not transitional but uniquely specific. However, it is crowded hard by

the climax beech-sugar maple-ash type where soil moisture becomes somewhat mesophytic. This characteristic stands out prominently as one travels westward from Osgood on highway 421. The sweet gum-red maple-beech type of forest stops "on a line" a few miles east of Greensburg as proximity to streams affords more effective drainage of the plain. It is, thus, a very fascinating forest association to study ecologically. In the seven stands included here *Acer saccharum* is almost entirely wanting in the forest association.

A striking characteristic is also the large number of species which have a F. I. above 50 per cent, differing in this respect from the climax forest for the same region, as reported by Potzger (6). Of the characteristic dominants *Acer rubrum*, *Fagus*, *Carya ovata* and *Nyssa* show a wide range of habitat tolerance, and there is good reason to suspect that varieties or ecotypes parade under the same taxonomic designation, and so offer a challenge to taxonomists for critical study.

For comparison of the stands in the process of succession with an undisturbed mature sweet gum-red maple-beech stand we have the record of the Klein woods, studied quantitatively by Keller (4) before it was lumbered a few years later. In gross features of the associates it is essentially like the stands considered in the present study.

Different types of sweet gum-red maple-beech-pin oak forests appear already in the successional stages, they are determined by greater or lesser abundance of the dominant species, even though fidelity of species within the association is very high. In terms of percentage they are: *Acer rubrum* 100, *A. saccharum* 70, *Carya ovata* 86, *Fagus grandifolia* 86, *Fraxinus americana* 100, *Liriodendron* 86, *Liquidambar* 100, *Nyssa sylvatica* 100, *Quercus alba* 70, *Q. palustris* 100, *Q. rubra* 70, *Ulmus americana* 100.

Soil moisture is perhaps the most important single control factor. As representative examples we refer to the Peetz woods (table 3), a poorly drained area, and the Huneke woods (table 2) on a better drained area. We note that *Acer rubrum* and *Liquidambar* are not affected by the degree of difference in the edaphic factor, but *Carya ovata*, *Fagus*, *Fraxinus americana*, *Quercus alba* and *Q. rubra* indicate preference for better drained soil.

In a way, secondary succession is non-existent for these till plain forests. Liquidambar and *Acer rubrum* are non-replacing immediate invaders of cut-over forests on old fields. Secondary succession in this unique forest is merely a multiplication of numbers of the dominants and reduction in abundance of the various associates. As Potzger and Potzger (7) and Chapman (3) point out, succession is a process of invasion of groups of the dominants determined by age of the stand. According to results obtained from this study the progress of succession is not greatly influenced by degree of disturbance, except that in lumbered areas more of the dominants participate from the beginning than in cleared fields, and so mature forest conditions are obtained more quickly.

SUMMARY AND CONCLUSIONS

1. The study deals with secondary succession in seven stands of sweet gum-red maple-beech-pin oak type of forest in Ripley County, Indiana.

2. Three stands began after disturbance by lumbering, three from cleared not farmed fields and one from an abandoned field.

3. Secondary succession on Illinoian till plain habitats is a process of different groups of the dominants entering the association at different time intervals which influences abundance of the various dominants but does not replace species of trees in succession of seres.

4. Sweet gum, red maple and American elm are most abundant in the young stands.

5. While in general the same forest type is evident in stands beginning after lumbering as from cleared fields succession from fields requires more time for all associates of mature forests to enter the association.

6. Difference in soil moisture (apparently) induce various types of sweet gum-red maple-beech-pin oak forest covers, determined by variation in abundance of the participating dominants.

7. Fidelity of the dominants is high in the seven stands, and more species (five to seven) have a F. I. above 50 per cent than in the climax mixed hardwoods.

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TABLE 1

Tabulation of woody species in forty 10-meter-square quadrats in the Reinking woods. Size-classes in inches.

Species	Below .1 in.	1-2	3-5	6-9	10-15	Above 15	Total stems	% F. I.
<i>Acer rubrum</i>	21	28	45	19	5		118	78
<i>A. saccharum</i>	5						5	13
<i>Carpinus caroliniana</i>	8	9					17	20
<i>Carya cordiformis</i>	2						2	3
<i>C. glabra</i>	4	7	3				14	20
<i>C. ovata</i>	13	18	20	5			56	60
<i>Cornus florida</i>	2	1					3	3
<i>Fagus grandifolia</i>	17	34	11				62	95
<i>Fraxinus americana</i>	14	7	24	10	2		57	75
<i>F. nigra</i>	1						1	3
<i>Juniperus virginiana</i>	1						1	3
<i>Liriodendron tulipifera</i>	3			1	1		5	12
<i>Liquidambar styraciflua</i>	2	2	9	7	2		22	40
<i>Nyssa sylvatica</i>	5	9	14	2	4		34	30
<i>Populus deltoides</i>					1		1	3
<i>Populus grandidentata</i>					2		2	3
<i>Prunus serotina</i>	8						8	5
<i>Quercus alba</i>		1	7	8	2		18	28
<i>Q. bicolor</i>		1	5	9	4		19	28
<i>Q. palustris</i>	1	1	10	50	36	2	100	87
<i>Q. rubra</i>			5	6	2		13	17
<i>Q. velutina</i>	1						1	3
<i>Sassafras albidum</i>	11			2			13	17
<i>Ulmus americana</i>	108	69	44	19	1		241	83

TABLE 1—(Continued)

Tabulation of woody species in forty 10-meter-square quadrats in the Reinking woods. Size-classes in inches.

Species	Below .1 in.	1-2	3-5	6-9	10-15	Above 15	Total stems	% F. I.
<i>Aralia spinosa</i>	4						4	3
<i>Lindera benzoin</i>	95						95	37
<i>Sambucus canadensis</i>	1						1	2
<i>Smilax glauca</i>	16						16	17
<i>Viburnum dentatum</i>								
var. <i>deamii</i>	1						1	2
<i>V. prunifolium</i>	1						1	2

TABLE 2

Tabulation of woody species in twenty 10-meter-square quadrats in the Woodrow Huneke woods. Size classes in inches.

Species	Below 1 inch	1-2	3-5	6-9	10-11	Total stems	% F. I.
<i>Acer rubrum</i>	69	71	51	12	2	204	100
<i>Carpinus caroliniana</i>	26	32	8			66	55
<i>Carya ovata</i>	22	77	44	4		169	100
<i>Fagus grandifolia</i>	39	49	11			138	90
<i>Fraxinus americana</i>	10	36	17	5		78	85
<i>Liquidambar styraciflua</i>	2	44	88	30		166	100
<i>Liriodendron tulipifera</i>				1		1	5
<i>Morus rubra</i>		1				1	5
<i>Nyssa sylvatica</i>	1	5	2			8	30
<i>Prunus serotina</i>				1		1	5
<i>Quercus alba</i>		1	2			3	10
<i>Q. palustris</i>	1	1	2	2		6	20
<i>Q. rubra</i>		4	4	5	1	14	45
<i>Salix</i> sp.?			1			1	5
<i>Sassafras albidum</i>	9	2	5	3		19	40
<i>Ulmus americana</i>	49	42	16	4		111	95
<i>Aralia spinosa</i>	1					1	5
<i>Lindera benzoin</i>	71					71	50
<i>Smilax glauca</i>	46					46	35
<i>Vitis</i> sp.?	9					9	20

TABLE 3

Tabulation of woody species in twenty 10-meter-square quadrats in the Clyde Peetz woods. Size-classes in inches.

Species	Below 1 inch	1-2	3-5	6-9	10-15	Total stems	% F. I.
<i>Acer rubrum</i>	33	92	101	68	3	297	100
<i>Carya ovata</i>	14	9	1	1		25	50
<i>Fagus grandifolia</i>	16	18	1	2		37	70
<i>Fraxinus americana</i>	13	12	19	5		49	70
<i>Liquidambar styraciflua</i>	4	13	30	23	1	70	75
<i>Liriodendron tulipifera</i>	5	1	4	10	1	21	45
<i>Nyssa sylvatica</i>	30	14	1			45	35
<i>Quercus palustris</i>	2	1	9	1	2	15	30
<i>Sassafras albidum</i>	15		3	4		22	20
<i>Ulmus americana</i>	18	37	15		1	71	85
<i>Aralia spinosa</i>	3					3	10
<i>Corylus americana</i>	10					10	5
<i>Ilex verticillata</i>	3					3	5
<i>Lindera benzoin</i>	34					34	55
<i>Sambucus canadensis</i>	1					1	5
<i>Smilax glauca</i>	50					50	70
<i>Viburnum</i> sp.?	2					2	10
<i>Vitis</i> sp.?	13					13	50

TABLE 4

Tabulation of woody species in twenty 10-meter-square quadrats in the Fangman woods. Size-classes in inches.

Species	Below 1 in.	1-2	3-5	6-9	Total stems	% F. I.
<i>Acer rubrum</i>	570	516	77	6	1169	100
<i>Carpinus caroliniana</i>	70	25	1		96	60
<i>Carya ovata</i>	6	14			20	55
<i>Carya</i> sp.?	2	1			3	5
<i>Fagus grandifolia</i>	11	1			12	30
<i>Fraxinus americana</i>	4	3			7	35
<i>F. pennsylvanica</i>	2	1			3	10
<i>Liquidambar styraciflua</i>	99	149	94	18	360	100
<i>Liriodendron tulipifera</i>	2	1			3	15
<i>Morus rubra</i>	2	1			3	5
<i>Nyssa sylvatica</i>	22	19	4		45	60
<i>Ostrya virginiana</i>	1				1	5
<i>Populus tremuloides</i>	8	4	4		16	20
<i>Platanus occidentalis</i>			1		1	5

TABLE 4—(Continued)

Tabulation of woody species in twenty 10-meter-square quadrats in the Fangman woods. Size-classes in inches.

Species	Below 1 in.	1-2	3-5	6-9	Total stems	% F. I.
<i>Quercus alba</i>	1				1	5
<i>Q. palustris</i>	22	32	20	5	79	25
<i>Q. rubra</i>	2	1			3	15
<i>Sassafras albidum</i>	2				2	10
<i>Ulmus americana</i>	101	39	2	1	143	80
<i>Amelanchier canadensis</i>	1				1	5
<i>Corylus americana</i>	336				336	70
<i>Hamamelis virginiana</i>	4				4	5
<i>Ilex verticillata</i>	245				245	50
<i>Rhus</i> sp.?	5				5	10
<i>Rosa</i> sp.?	90				90	55
<i>Salix</i> sp.?	32	9			41	50
<i>Smilax rotundifolia</i>	110				110	60
<i>Viburnum dentatum</i> var. <i>deamii</i>	35				35	45
<i>Parthenocissus quinquefolia</i>	15				15	25
<i>Vitis</i> sp.?	38				38	70

TABLE 5

Tabulation of woody species in twenty 10-meter-square quadrats in the Estol Ehlers south woods. Size-classes in inches.

Species	Below .1 inch	1-2	3-5	6-9	10-15	Above 15	Total stems	% F. I.
<i>Acer rubrum</i>	81	111	66	1			259	100
<i>A. saccharum</i>		9	3	1			13	15
<i>Carpinus caroliniana</i>	29	36	9		1		75	40
<i>Carya cordiformis</i>	4	6	2		1		13	40
<i>C. ovata</i>	16	20	8	1			45	65
<i>Cornus florida</i>	5						5	5
<i>Fagus grandifolia</i>	10	1	3	2			16	15
<i>Fraxinus americana</i>	1		1		1		3	15
<i>Juniperus virginiana</i>	1						1	5
<i>Liriodendron tulipifera</i>	7	8	3				18	15
<i>Liquidambar styraciflua</i>	30	45	44	1	1		121	85
<i>Nyssa sylvatica</i>	77	80	11	5	2		175	100
<i>Populus grandidentata</i>		1	1	2			4	10
<i>Prunus serotina</i>		1					1	5
<i>Quercus bicolor</i>		1	4	4			9	10
<i>Q. palustris</i>	2	9	13	4	3	1	32	80

TABLE 5—(Continued)

Tabulation of woody species in twenty 10-meter-square quadrats in the Estol Ehlers south woods. Size-classes in inches.

Species	Below .1 inch	1-2	3-5	6-9	10-15	Above 15	Total stems	% F. I.
<i>Q. rubra</i>	1	1	2	3			7	15
<i>Sassafras albidum</i>		3	4				7	15
<i>Ulmus americana</i>	39	30	21	3			93	85
<i>U. rubra</i>	13	5	3	2			23	45
<i>Aralia spinosa</i>	21	2	1				24	30
<i>Lindera benzoin</i>	24						24	35
<i>Rosa</i> sp.?	9						9	20
<i>Sambucus canadensis</i>	4						4	5
<i>Smilax glauca</i>	2						2	10
<i>Vitis</i> sp.?	24						24	70

TABLE 6

Tabulation of woody species in twenty 10-meter-square quadrats in the Estol Ehlers north woods. Size-classes in inches.

Species	Below .1 inch	1-2	3-5	6-9	10-15	Total stems	% F. I.
<i>Acer rubrum</i>	282	246	106	5		639	95
<i>A. saccharum</i>	1	1				2	10
<i>Carya cordiformis</i>		1	3	1		5	20
<i>C. ovata</i>	4	7	4	1		16	30
<i>Fraxinus americana</i>		1	2	1		4	10
<i>Liquidambar styraciflua</i>	28	28	34	12	1	103	90
<i>Nyssa sylvatica</i>	54	38	19	1		112	100
<i>Populus grandidentata</i>			7	2		9	15
<i>Quercus alba</i>	2	2		1	3	8	20
<i>Q. palustris</i>	7	1	13	15	9	45	90
<i>Q. rubra</i>	10					10	15
<i>Ulmus americana</i>	458	269	34	1		762	100
<i>U. rubra</i>	15	3				18	25
<i>Amelanchier canadensis</i>	1					1	5
<i>Aralia spinosa</i>	1					1	5
<i>Rosa</i> sp.?	28					28	35
<i>Vitis</i> sp.?	12					12	25

TABLE 7

Tabulation of woody species in twenty 10-meter-square quadrats in Versailles State Park. Size-classes in inches.

Species	Below 1 inch	1-2	3-5	Total stems	% F. I.
<i>Acer rubrum</i>	223	278	9	510	100
<i>A. saccharum</i>	1			1	5
<i>Carpinus caroliniana</i>	1			1	5
<i>Cornus florida</i>	2	1		3	5
<i>Fagus grandifolia</i>	1			1	5
<i>Fraxinus americana</i>	17			17	55
<i>Juniperus virginiana</i>	3	1		4	15
<i>Liquidambar styraciflua</i>	158	343	72	573	100
<i>Liriodendron tulipifera</i>	55	14	1	70	75
<i>Nyssa sylvatica</i>	17	4		21	35
<i>Platanus occidentalis</i>	4	1		5	15
<i>Populus grandidentata</i>	26	2		28	30
<i>Prunus serotina</i>	4	2	1	7	20
<i>Quercus alba</i>	2			2	10
<i>Q. bicolor</i>	3			3	10
<i>Q. rubra</i>	1			1	5
<i>Sassafras albidum</i>	5	1		6	25
<i>Ulmus americana</i>	5	1		6	20
<i>Campsis radicans</i>	545	1		546	50
<i>Rhus glabra</i>	11	1		12	10
<i>Salix</i> sp.?	63	1		64	35
<i>Viburnum dentatum</i> var. <i>deamii</i>	21			21	5
<i>Vitis labrusca</i>	79			79	45

RELATION OF CERTAIN VEGETATIVE CHARACTERISTICS OF *Stipa spartea* TO SURVIVAL FROM DEFOLIATION

By JOHN F. PELTON, Butler University

INTRODUCTION¹

If it were possible to find readily observable morphological features by which survival of grasses subjected to overgrazing might be predicted it would doubtless be of considerable use in range management practice and research. Reliability of estimates of the condition of the range would thereby be appreciably increased, a much needed goal in the management of grasslands. This paper is a report on experiments designed to test the correlation between several readily measurable criteria of size and apparent vegetative vigor of individual bunches of porcupine grass, *Stipa spartea* Trin., and their survival from defoliation.

The experiment was planned to test the hypothesis that those individual bunches which are vegetatively moderately vigorous compared to the obviously less thrifty individuals, and at the same time are larger than a certain minimum size limit, would best tend to survive severe defoliation. In order to reduce the subjectivity involved in estimates of size and vegetative vigor these were measured quantitatively as described below. Size and vigor were based on characteristics which could be readily determined in most species of bunch grasses, namely basal area, shoot number, and shoot weight.

Porcupine grass is a medium to large sized bunch grass conveniently adapted to a study of this sort. Certain aspects of its ecology not here discussed have been described by Weaver and Fitzpatrick (6, 7), Weaver and Albertson (8, 9), R. J. Weaver (11), and Robertson (4).

¹ It is a pleasure to express my indebtedness to Dr. and Mrs. Donald B. Lawrence of the University of Minnesota, Dr. W. E. Gorden of the Nashville School of Social Research, Dr. L. Ellison of the Intermountain Forest and Range Experiment Station, and especially to my wife, Jeanette S. Pelton, for invaluable assistance during the course of this investigation.

PROCEDURE

The experiment was performed on a relatively undisturbed site of prairie vegetation (locally known as Bunker Prairie) 17 miles north of Minneapolis, Minnesota, in Anoka County, and lasted from early spring of 1947 through the spring of 1948. Plots were established on the gently southwest facing windward slope of one of the numerous and now stabilized dune ridges characterizing the general locality, the physiographic history of which has been described by Cooper (2).

The soil on the experimental area is a uniform and deep fine sand, classified in the Hinckley series by Smith, et al (5). The plants near the lower part of the ridge were in a relatively moister situation, but nowhere was the soil on the experimental area sufficiently moist to support trees or large shrubs. *Stipa spartea* dominated the site but with a scattered admixture of *Koeleria cristata* (L.) Pers., *Calamovilfa longifolia* (Hook.) Scribn., *Poa pratensis* L., *Carex pensylvanica* Lam., *Andropogon scoparius* Michx. and *A. gerardi* Vitman, *Aster* spp, *Solidago* spp, and others.

Since the area was located in a state game refuge grazing by livestock had been prevented for some time, and deer were scarce. Fire had not passed over the area for at least several years. Some grasshopper injury, however, occurred during the course of the study, but since it occurred rather uniformly and not excessively over the entire experimental area the results of the experiment were probably not appreciably altered.

Eight rows of plots were located in an area about 80 feet long and 30 feet wide. Each plot was one meter wide and of variable length chosen to include exactly twenty *Stipa* bunches, one meter being left between successive plots in a given row. Each individual *Stipa* was marked with a numbered stake, a total of 760 bunches being included in the study. Genetic differences between individuals were probably at a minimum because of the small area and population involved and the relatively uniform habitat.

Size of the individual clumps of *Stipa* was measured by three methods: (1) Total number of live shoots, (2) Total dry weight of live shoots, (3) Basal area of the clump. These were determined by clipping all the overwintered dead foliage from the plants at a

height of one inch in very early spring before growth had started. The numbers of live shoots were determined by counting all shoots possessing any green tissue within the dead outer leaf sheaths of the preceding year. This procedure was possible owing to the live shoot bases of this species normally remaining green throughout the winter.

Dry weight was determined from the dead foliage thus collected from each plant and oven dried in individual numbered paper bags. That this previous year's foliage was highly correlated as a measure of relative size with the growth of the current season was shown by clipping twenty plants later in the spring and weighing this new leafage. The rank correlation coefficient between the dead and living foliage used in this way as relative measures of size was 0.97 in this test.

Basal area was obtained by tracing the outline of the bunch at ground level (as estimated at the clipping height of one inch) on a glass plate with a wax pencil. The form thus obtained was traced again onto a sheet of paper and its area later measured with a planimeter. Approximately 3% of the plants on the plots were doubtful as to individuality because of the gradual breaking up of an original clump into several, or the fusion of two adjacent clumps, and these were omitted from the study.

Three criteria of relative vegetative vigor of the bunches were utilized, all derived from the above types of measurements of plant size. These were: (1) Number of live shoots per square inch of basal area, (2) Dry weight of live shoots per square inch of basal area, (3) Average shoot weight for a given clump. The first criterion is based on the idea that the more vegetatively vigorous plants will have denser shoots and foliage, as measured at ground level. Sparse and scattered shoots would then suggest low vigor. The weight of foliage per unit of basal area also is a measure of its density as well as of other characteristics such as average shoot size. The third criterion, average shoot weight, is assumed by this theory to indicate that the bunches of greater vegetative vigor will have heavier than average shoots.

After the plants had been classified according to size and vigor as based upon the growth of the previous season, defoliation treatments by means of clipping were initiated. The experimental popu-

lation was divided into two groups of 380 plants each, alternating sets of twenty clumps being placed in a group. One group was clipped so frequently that by the following spring (May 2) 74.6% were dead. The other group, clipped less frequently, suffered a 19.8% mortality. All clipping was done at a height of one inch, and only the frequency and season were varied. The experiment was not designed to distinguish between the relative importance of frequency and season of defoliation in causing the mortality observed.

The frequently clipped group was cut six times between May 20 and June 30 at about weekly intervals. It was then seen that the mortality rate would be excessively high if clipping were not stopped. Consequently, the plants were not cut again until October 25 at the end of the growing season. The infrequently clipped group was allowed to grow until seed had matured, about July 13, before cutting. They were not again clipped until August 28, and finally on October 25.

Apparent time of death was recorded for each bunch individually. Complete loss of all green leaves and green leaf bases was the criterion for recording a clump as dead. No plant recorded as dead in the fall was observed to recover the following spring, although about 15% of additional clipped plants died during the winter. That these winter fatalities were at least indirectly due to clipping is shown by the observation that no unclipped plants died during either the summer or winter in the study area.

RESULTS

An analysis of the relation between the vegetative characteristics used and survival was made by the Chi-square technique of testing significance. The results are summarized in Table I. Large size, as measured either by total shoot weight or total number of shoots, favored survival to a statistically significant extent in only the less frequently clipped plants. The association between size and survival was weak or non-existent where size was measured by basal area, reaching a significance level of only 0.10. The association of size and percentage survival in the less severely cut group is readily seen in graphic form in figure 1. The general trend of better survival with increasing size appears to be fairly consistent.

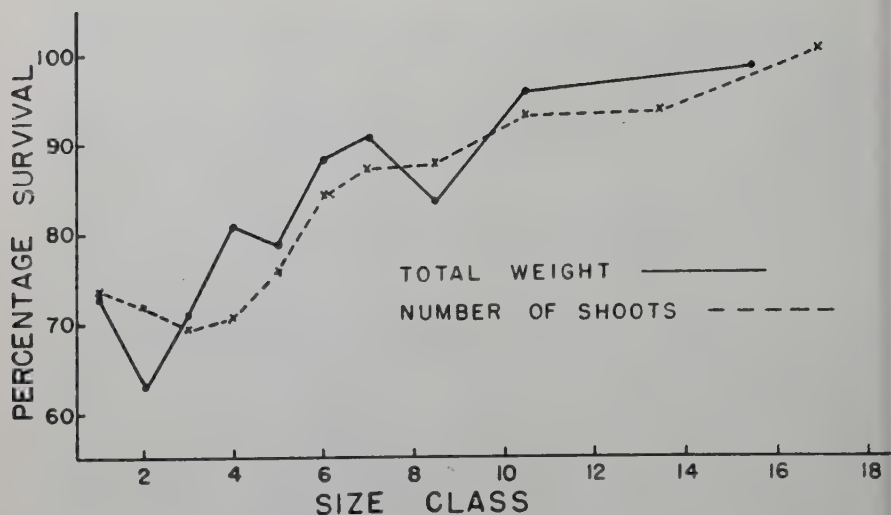


Fig. 1. Survival as related to total weight and number of shoots under the less frequent clipping treatment. The classes are in the order of increasing magnitude.

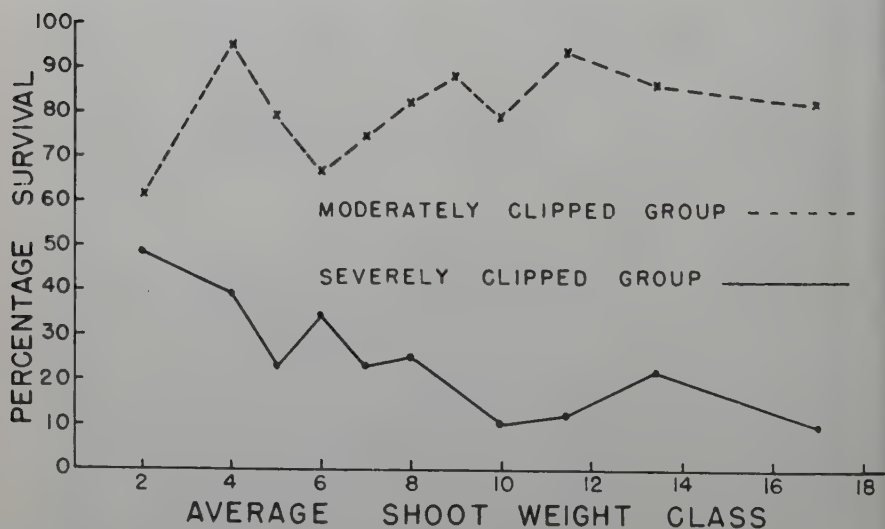


Fig. 2. Survival as related to average shoot weight of both frequently and infrequently clipped plants. The classes are in the order of increasing magnitude.

Two of the measures of vegetative vigor, number of shoots per square inch and weight of shoots per square inch, had no measurable correlation with survival under either clipping treatment. Average shoot weight, on the other hand, seemed definitely associated with survival under both treatments. The results in this case, however, are conflicting. Among the frequently clipped plants those with heavy shoots tended to have a lower survival rate than clumps with lighter weight shoots, while the reverse relation seems to hold under the less frequent cutting treatment (Fig. 2).

In view of some of these conflicting results a further analysis of the interrelations of the various measures of size and vigor would seem desirable. The frequencies of the measure used are shown in figure 3. The three measures of size are all seen more or less to agree in the large number of small plants. Of the measures of vegetative vigor, both weight and number of shoots per unit of basal area appear to follow a frequency pattern which is similar to those of the measures of size. That is, plants which have a small number or weight of shoots per square inch of basal area predominate in numbers. Average shoot weight, however, more nearly approaches the normal curve in its distribution although there is still a larger proportion of plants with light-weight shoots than with heavy shoots.

If each measure of size and of vegetative vigor is plotted against every other measure of size and vigor used in this study a total of fifteen possible combinations may be obtained. Three examples representing the general patterns that were obtained in this fashion are illustrated in figures 4, 5, and 6. In order to reduce the size of the charts the outer extreme one per cent of the cases is omitted, although these were included in calculating the regression line.

The trend represented by figure 4 approaches a straight line with a strongly positive slope. It was characteristic of all charts where one measure of size was plotted against any other measure of size, and also where weight per square inch and number of shoots per square inch were plotted against one another. It is apparent from the scatter in figure 4 that the degree of correlation is not high, although it is greater where weight and number, or area and number, are plotted. Field observations had previously suggested that close correlation between basal area and weight or number of shoots should not be expected, for it frequently occurred that clumps which pos-

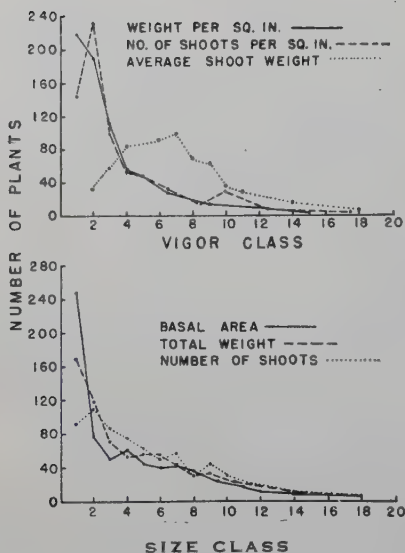


Fig. 3. Frequencies of the characteristics used in estimating size and vegetative vigor. The classes are in the order of increasing magnitude.

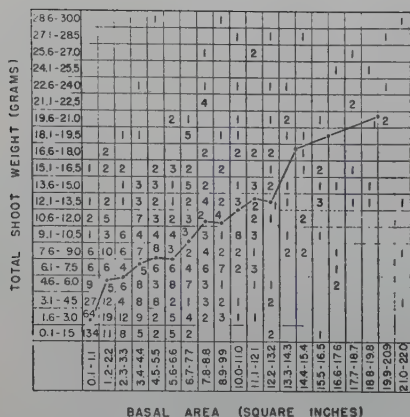


Fig. 4. Scatter diagram of basal area and total shoot weight.

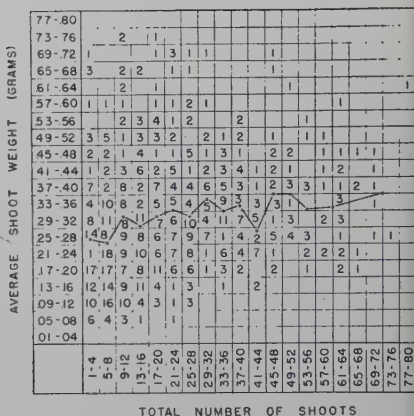


Fig. 5. Scatter diagram of total number of shoots and average shoot weight.

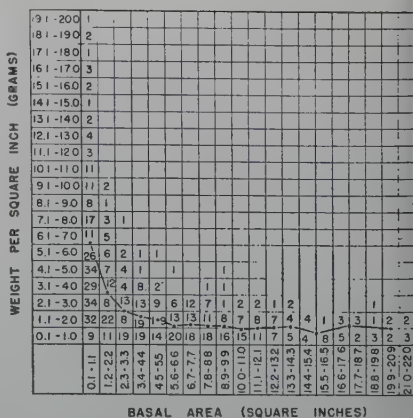


Fig. 6. Scatter diagram of basal area and weight of shoots per square inch.

sessed large basal areas often exhibited few and scattered shoots of small total weight. In fact, the decision to use the number or weight of stems per unit of basal area as measures of relative vegetative vigor was largely prompted by this observation.

Figure 5 illustrates the general trend and scattering which resulted whenever average shoot weight was included as one of the variables. In general the slope is positive but slight or even horizontal in several cases, and the scatter is considerable. The slope is greater, however, where average shoot weight is plotted against total shoot weight, suggesting even more than does figure 5 that as the size of the plant increases so does the average weight of the individual shoots. This relationship is almost non-existent, however, where size is measured by basal area.

A distinctive type of relationship is that represented by figure 6, one in which the trend is at least initially strongly negative and curvilinear, and in which the scatter is small. Such a curve resulted whenever either weight per square inch or number of shoots per square inch were plotted against any of the measures of size, with one exception (weight per square inch times total shoot weight) in which a linear and horizontal trend was obtained.

DISCUSSION

The inconsistencies apparent in the results described above raise some fundamental problems concerning the existence of other plant characteristics which might be more reliable in indicating resistance to defoliation than those here used. The results of this experiment suggest that if these exist they will in all likelihood not be conveniently observed or measured properties. Useful characteristics will most likely be such difficult to measure morphological features as the depth and spread of the root system or the root-shoot ratio, or physiological characteristics such as the amount of reserve foods in roots and shoot bases. The time-consuming though promising method of measuring vigor described by Weaver and Darland (10) uses several morphological measures, but there is no evidence that plants classified as vigorous by this method are actually able to withstand grazing better. The potentialities of chemical analysis in estimating survival ability is suggested in the work of Rather and Harrison (3) in which it was found that the food reserves of alfalfa

plants in a pasture subjected to grazing were a measure of their survival and recuperative vigor. Ability to reproduce satisfactorily over a period of time has been used as a criterion of vigor in a broad sense, as by Braun-Blanquet (1). In this usage reproduction by either vegetative means or by the production of seeds could be used as a measure of vigor.

The inconveniences of all these methods of estimating survival ability will, however, tend to prevent their routine use in range management practice. It is still quite probable that some easily measured morphological characteristics may be found to be usefully correlated with ability of the plant to survive overgrazing. If these occur, however, they may be expected to vary considerably with the species, with the habitat, and with the previous treatment to which the plants had been subjected, and hence would certainly have to be applied with caution.

It might be expected that excessive vegetative vigor might as well indicate susceptibility as resistance to defoliation, just as it often indicates susceptibility to cold injury. In the area of the present study, however, no plants of *Stipa spartea* seemed to fall into the category of unusual vegetative vigor owing to the infertile sandy soil of the locality. It would be most interesting to repeat the experiment in a region where a much greater range of vegetative vigor of *Stipa* is available.

Weaver and Albertson (8) observed that the first individuals of *Stipa spartea* to succumb to drought were the very young and the very old plants. Age was here undoubtedly estimated by size of the individual clumps. Age is, however, probably closely proportional to size only in an exceedingly uniform environment populated by one or only a few biotypes. In the present experiment the environmental conditions were probably varied enough so that size of the clumps was a very undependable measure of age. If only plants of a given age were compared, a more consistent and dependable relation of size to survival would probably have been obtained. Unfortunately, age determinations of bunch grasses are generally impracticable under natural conditions after the first two or three years following germination.

Some of the inconsistencies in the relation of survival to those characteristics used in the present work are understandable in the

light of their relation to one another. Thus it is evident from figure 4 that a plant classified as large by basal area measurements might be considered small if weight were the criterion. Figure 6 shows that plants considered vegetatively vigorous by the criterion of weight of shoots per unit of basal area occur mainly in the smallest size classes. Yet if vegetative vigor is believed associated with high average weights of the individual shoots of a clump then the larger plants, as measured by number of shoots in figure 5, tend to be considered the more vigorous instead of the smaller ones. Thus average shoot weight appears to contradict both of the other two measures of vegetative vigor used in this study, weight or number of shoots per unit of basal area. These facts would seem to emphasize the need for clear and specific use of the terms size and vigor in referring to bunch grasses.

SUMMARY

The bunch grass *Stipa spartea* was utilized in an experiment designed to test the relation of size and vegetative vigor of individual naturally-grown plants to their survival from defoliation.

Three measures of clump size were used, basal area, number of shoots, and weight of shoots. Three criteria of vegetative vigor were obtained from these values, and expressed as number and weight of shoots per unit of basal area, and average shoot weight.

Two equivalent groups of plants were subjected to different intensities of defoliation: Frequent clipping which resulted in nearly 75% mortality, and less frequent removal of foliage causing less than 20% mortality.

The results of significance tests suggest that the larger plants tended to survive better than smaller bunches under the less severe treatment. No correlation of size and survival was obtained with more severe defoliation. The results with the measures of vigor indicate either no correlation at all, or an inconsistent one in the case of average shoot weight.

The necessity for clear and specific use of the terms size and vigor is emphasized by the lack of agreement present among several of the criteria commonly used in judging them. The potential value in estimating survival ability of some criteria not used in the present study is evaluated.

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TABLE I

A summary of the relations of size and vegetative vigor to survival from defoliation. Those values marked with an asterisk (*) indicate statistically significant correlations at the 5% level of significance.

Plant characteristic	Probability of Chi-square	
	Frequently cut plants	Infrequently cut plants
Total shoot weight	0.80	0.001*
Total number of shoots	0.60	0.012*
Basal area	0.71	0.10
Weight per square inch	0.48	0.47
Number shoots per square inch	0.39	0.68
Average shoot weight	0.006*	0.029*

EFFECT OF FIVE ANTIBIOTICS IN VARYING CONCENTRATIONS ON GROWTH OF YOUNG CORN PLANTS*

By WILLIAM E. HARRIS

The products of microorganisms collectively known as antibiotics, have been investigated extensively as aids to medical sciences, but they have not been thoroughly studied for possible other uses. Several papers have appeared in recent years concerning work done on antibiotic stimulation of growth in such domestic animals as young pigs (1) and chicks (2), the addition of certain antibiotics, notably penicillin and streptomycin, to commercial feeds becoming somewhat general. It is also well known that certain antibiotics in very low concentration may stimulate growth of some bacteria (3). Most work involving higher plants dealt with antibiotic effects on germination of seeds, and growth characteristics were not noted.

For normal growth, many higher plants require a symbiotic relationship with some bacteria and/or a mycorrhizal relationship with some fungi (4), and since most antibiotic substances come from soil microorganisms it seemed likely that antibiotics in low concentration might affect plant growth. It was for this reason that the present study of effects of five antibiotics on growth of young corn plants was undertaken. This study is exploratory, intended to cover a wide range of antibiotics in varying concentrations to discover any possible growth stimulation or inhibition.

METHODS

In this study certain experiments were designated "pilot experiments," and others "confirmatory experiments." Pilot experiments were those in which several concentrations of antibiotics were tested on fewer plants so that there would be a better chance of discovering an antibiotic concentration capable of producing growth effects on the plants. Confirmatory experiments were those using one concentration of an antibiotic which appeared to affect the growth of test

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plants in a pilot experiment on a larger number of test and control plants.

Test plants for all pilot experiments (Ex. I, II, IV-VI) were equally spaced in six rows of twelve plants each, with about three inches between each row. Each plant in five of these rows was treated with 25 ml. of five selected antibiotic concentrations four times a week, one concentration per row. The sixth row as a control was watered only with tap water. Plants were grown for five weeks, but treated only the last four weeks, making a total of 16 antibiotic applications. After 16 applications, each plant had been treated with the following quantities of antibiotic:

Control Group		0.0 Mg.
.5 PPM "		.2 Mg.
1 " "		.4 Mg.
3 " "		1.2 Mg.
5 " "		2.0 Mg.
10 " "		4.0 Mg.
20 " "		8.0 Mg.

Test plants of confirmatory experiments (Ex. III, VII) were placed in two groups and given equal light exposure. These plants were watered and treated four times a week in the same manner as were the plants in pilot experiments.

After five weeks it was found that the plants were root-bound in the pots and it was deemed advisable to halt tests at that point.

Seven experiments utilizing five antibiotics were accomplished:

Experiment I was a pilot experiment testing five concentrations of potassium penicillin (.5, 1, 3, 5, and 10 PPM or Mcg/ml.) on growth of corn plants. Twelve corn plants were treated with each concentration of antibiotic and twelve plants were left untreated for control.

Experiment II was a pilot experiment testing five concentrations (.5, 1, 3, 5, and 10 PPM or Mcg/ml.) of procaine penicillin on young corn. Again twelve plants were treated with each concentration and twelve untreated plants were used as control.

Experiment III was a confirmatory experiment testing the reliability of one concentration (5 PPM) from experiment I. 36

treated plants were used, and 36 plants were left untreated for controls.

Experiment IV was a pilot experiment testing five concentrations (.5, 1, 3, 5, and 10 PPM or Mcg/ml.) of the antibiotic bacitracin, utilizing twelve untreated plants for each concentration and twelve untreated plants for control.

Experiment V was a pilot experiment testing five concentrations (1, 3, 5, 10, and 20 PPM or Mcg/ml.) of the antibiotic erythromycin. Twelve corn plants were used for each concentration and twelve untreated plants were for control.

Experiment VI was a pilot experiment testing five concentrations (1, 3, 5, 10, and 20 PPM or Mcg/ml.) of the antibiotic streptomycin sulfate. Once more twelve plants were treated with each concentration and twelve plants were left untreated for control.

Experiment VII was a confirmatory experiment testing further one concentration of experiment V (5 PPM). 36 plants were treated, and 36 were left untreated as controls. The 36 control plants were dried and weighed in three groups of 12 plants each.

Plants were measured for height in Cm. approximately one week after planting (just before first treatment) and weekly thereafter. The height of the plants was measured when turgid as the tallest plant part from soil level, either leaf tip or leaf midsection. After four weeks of treatment the corn plants were cut off at ground level and all plants from a single concentration were placed in a previously weighed 800 ml beaker. The beaker and its contents were weighed immediately for wet weight, then placed in an oven at 105°C for 48-72 hours. The beaker and contents were then weighed again to obtain dry weight.

Funk's G-99 hybrid corn seed was used for all tests. The seed was planted two seeds per four inch flower pot: then upon germination where two seeds grew and germinated in the same pot, one was removed. Thus when antibiotic treatment was begun, one corn plant was growing in each plot. Temperatures were regulated as accurately as possible near 80°F. The plants were watered as needed, except that anytime test plants were treated with antibiotic solution, a volume of water equal to the volume of antibiotic solution was ap-

plied to the control plants. An attempt to keep humidity normal was made by placing pans of water under benches in each greenhouse compartment. All plants from a single experiment were always grown in the same compartment, and where tests on two antibiotics were run simultaneously, a different greenhouse compartment was used. The glass was removed from a partition between two compartments for better air circulation and to equalize temperature and humidity conditions between compartments. No auxiliary lighting was used, since the corn did grow satisfactorily in the winter sun, and any deficiency in growth of test plants due to less sunlight than is available during the normal growing season of corn would be cancelled by a like deficiency in growth of the control plants. Fertile loam soil known to be in good condition was used in all experiments.

The antibiotics were kept in a dry state at 20°C. Stock solutions of .2 g./liter concentration were made fresh weekly with distilled water. Prior to each treatment of corn plants, the stock solution was diluted with tap water to the desired concentration. The solutions were prepared on Mondays and last used on Fridays; thus no solution was over five days old when used. The antibiotic solutions used in the present study are known to be stable for this length of time when kept at 20°C. (5).

All antibiotics were of high purity, and had the following potencies (5):

Potassium penicillin G	1585 Units/Mg.
Procaine penicillin G	983 Units/Mg.
Bacitracin	528 Units/Mg.
Streptomycin sulfate	740 Mcg./Mg.
Erythromycin	965 Mcg./Mg.

A procedure to determine whether erythromycin was absorbed by the corn plants was carried out. Four plants which had been given five ml. of the .2g/ml. stock solution 24 hours preceding the extraction were extracted in the following manner:

The leaves of the four plants were cut into small pieces with scissors and then extracted with twenty ml. of water in a waring blender. Five control plants were treated in a like manner. This was essentially the method of Hayes (6) for extraction of antibiotic substances from higher plants, except that in this study scissors were

used for the initial maceration rather than a food grinder. The extracts from both treated and control plants were analyzed by a test for erythromycin sensitive to 4 Mcg./ml.

RESULTS

Results of the study are perhaps best understood if Tables I to VIII are studied. However, some results and observations which could not conveniently be incorporated in the tables or which are especially noteworthy are presented here.

Results of Experiment I utilizing potassium penicillin are shown in Table I. It is to be noted that although overall weight was less for treated than for control plants, dry weights for all treated (except .5 PPM) were greater than for control plants (Table I). The greatest increase in dry weight and wet weight over control occurred in the 5 PPM treated group. For the group in general it can be said that treated plants had higher dry and wet weight than controls.

Results of Experiment II using procaine penicillin are shown in Table II. The greatest dry weight occurred in the 3 PPM group which, although having final average height lower than control, weighed 10% more dry. Note that all other dry weights were less than or the same as the control, the .5 PPM group having only 80% dry weight of the controls. Height trends of Experiment II groups corresponded more nearly to dry weight trends of this group than it did in Experiment I.

The control plants of Experiments I and II were planted at the same time and grown under identical conditions. However, final measurements are somewhat different. Note that average height after 16 treatments was 25.3 Cm. for Ex. I control plants (Table I) and 23.4 Cm. for Ex. II control plants (Table II). Dry weight also varied, it being 4.3 g. for Ex. I control plants, and 4.9 g. for Ex. II control plants (Tables I and II).

Results of Experiment III, a more accurate reliability test on part of Experiment I (36 pots treated with 5 PPM potassium penicillin and 36 control plants), are shown in Table IV. Some significant points found in Table IV are, average height after 16 treatments for treated plants was 20.0 Cm. and for the controls average height was 22.5 Cm. The dry weight of treated plants was 6.7 g. however,

while that for controls was 6.1 g. As in the pilot experiment, the average height was less for treated but the dry weight was 10% more than control dry weight. While this experiment was being performed, the temperature of the greenhouse in which the plants were growing was allowed to become quite low several times. During this period also, many dark days occurred. This is evidenced by the low average weights and heights for this experiment in comparison with dry weights and heights of groups from other experiments.

Results of Experiment IV testing effects of bacitracin are shown in Table III. On a dry weight basis, control was higher than any treated group except the 5 PPM (Table III). Both final height and dry weight were more in the 5 PPM treated group than in control. The results of this experiment are somewhat questionable because the same weather and temperatures were encountered as in Ex. III since both were performed at the same time.

Results of Experiment V testing erythromycin are shown in Table V. In this experiment the greatest final average height was in the 10 PPM treated. Before treatment was begun, both the 20 PPM and control group had a higher average height than did the 10 PPM group, (control—5.8 Cm., 20 PPM—6.3 Cm., 10 PPM—5.0 Cm.). Dry weight shows the 5 PPM treated plants to weigh more dry than any other group. (Table V) The 10 PPM group, which it will be remembered were tallest, weighed less dry than controls and all treated excepting the 1 PPM group. (Table V)

Results of Experiment VI, testing streptomycin sulfate, are shown in Table VI. All treated groups, except the 20 PPM, had less final height than control. The 20 PPM treated had the greatest height of all treated groups. Dry weights showed control to weigh more than any treated except the 10 PPM group which weighed 1% more than the control group. The 20 PPM treated group, which had the greatest height, weighed the least dry of all groups. In general, treated plants weighed less dry than controls.

Results of Experiment VII are shown in Table VII. These results are practically duplicates of those observed in Experiment V (Table V). In Experiment V, the dry weight increase was 10% over control dry weight. In Experiment VII, the dry weight increase

over controls was 8%. The control plants when dried in three separate groups, of 12 plants showed the following weights per group:

Group I	4.5 g.
Group II	4.4 g.
Group III	4.1 g.

Tests sensitive to 4 Mcg/ml. for erythromycin presence in water extracts of control and plants treated with erythromycin 24 hours previously were both negative.

DISCUSSION

Growth is defined, perhaps somewhat imperfectly, as being increase in size, or increase in height and weight (7). In the present study, growth of corn plants was determined by three criteria:

1. Increase in length (height) of stem.
2. Increase in dry weight.
3. Increase in fresh (wet) weight.

These indices of growth are from six named by Meyer and Anderson (7).

In a study of this type, the problem of significance of results arises, i.e. is the phenomenon under consideration an artifact, or is it a result of the treatment administered by the investigator. It can be seen from the results that by consideration of the indices of growth mentioned above, in certain cases antibiotic treated corn plants grew larger than control plants, and in certain other cases control plants grew larger than treated plants. One can infer from these results that where a growth increase occurred, that concentration of antibiotic stimulated growth in respect to a wet and dry weight increase and/or a height increase. However results are such that one can infer that each antibiotic also inhibited growth at some concentration other than the concentration which supposedly stimulated growth. (Tables I-VIII). The question to be answered is, were these growth increases and decreases due to antibiotic treatment or to other factors which were beyond experimental control. Tables I-VIII show considerable inconsistency between dry weights and height measurements; that is, some groups weighing more than others had less average height. Due to their morphology, corn plants are

somewhat difficult to measure for height. In some cases, a plant which had the uppermost leaves vertical would be measured as taller than a more mature and often larger plant on which the uppermost leaves had bent downward. Therefore, not too much significance is attached to results dealing with height of the plants, and the remainder of this discussion will be concerned more with interpretations of dry weight increases and decreases.

It is well known that each living organism is an entity with its own physiological weaknesses and strong points. Although in these experiments only genetically pure seed was used, there could not help but be differences in growth capabilities of each seed; some plants should, under the same conditions, be able to grow larger in a given length of time than others because of this. It is thought that root and light competition did not enter in since the plants were grown in individual flower pots, and at the spacing they were given, serious overlapping of leaves did not occur. On the other hand, it is likely that in a study of this type, some plants might have available a slightly larger amount of water, and be exposed to a little more sunlight than others, thus in a few cases adding to the advantages of some plants over others.

It is admitted, therefore, that even in groups of 12 test and 12 control plants, some variations in height and weight may have been, and in a majority of cases probably were caused by factors other than antibiotic treatments. The growth effects of two groups of treated plants do appear to have been caused by antibiotic treatment. These are the 5 PPM group of Ex. I (potassium penicillin) and the .5 PPM group of Ex. II (procaine penicillin).

The results of the 5 PPM treated group in Ex. I are obviously most spectacular for growth increase. Here, where dry weight of the treated plants averaged 40% more than control, a growth stimulation of some sort cannot be denied. Since height of treated plants remained about equal to controls, it would mean that the treated plants weighed more per unit height than did the controls. In Experiment III the results were not so spectacular, the dry weight increase of treated plants being only 10% (Table IV). Since 36 plants in each group were measured and weighed in Ex. III it should have been more reliable, however, the facts that during the course of this experiment the plants were periodically subjected to some rather low

temperatures and there was much dark weather may have tempered the results, and perhaps if conditions had been more ideal, results more nearly approaching those of Experiment I would have occurred.

It has been shown that penicillin is taken up by higher plants (*Lepidium*), although the antibiotic is decomposed considerably in soil (8). Wright has shown that growing on agar on pH of 6.0, the root growth of wheat, white mustard and red clover seedlings is enhanced by penicillin at a 5 PPM concentration. The form, i.e. potassium penicillin, etc., was not named (9). These results tend to substantiate the indication that at a concentration of 5 PPM potassium penicillin stimulated growth of young corn plants in this study.

From Table II, it can be seen that growth of the .5 PPM procaine penicillin treated group was 20% less than that of the control group on a dry weight basis. Wet weight and height measurements are also somewhat lower indicating that at this concentration procaine penicillin seemingly inhibits growth. Reported cases where penicillin in such low concentration inhibits growth are lacking, and again the question of whether an actual inhibition due to penicillin action took place, or whether other factors are responsible for this inhibition arises. That the antibiotic treatment and other factors both are involved in this inhibition of growth is entirely possible. Since all treated groups of Ex. II have lower average height, lower wet weight, and all but the 3 PPM treated group have lower dry weight than controls it appears as if a general inhibition of growth for plants treated with various small amounts of procaine penicillin has taken place.

Since the antibiotic portion of the compound was the same in the potassium and procaine forms, one would think that results of Ex. I and Ex. II would be similar if not identical. However, the results of the treated groups in Ex. II are exactly opposite to the results in Ex. I. Remember that in Ex. II most treated groups weighed less dry than the controls, but in Ex. I, nearly all groups which were treated weighed more dry than did the controls. (Tables I, II, VIII.) After noting that corn treated with potassium penicillin generally grew larger than controls, while those treated with procaine penicillin generally grew less than controls, one recognizes the possibility of the growth stimulating and inhibiting causes resting with the cations potassium and procaine respectively rather than with the antibiotic anion penicillin. It is well known (7) that potassium is an essential

element for plant growth, and the small amounts of potassium added with the antibiotic could have had a stimulating effect especially if the soil should have been slightly deficient in potassium to begin with. Procaine on the other hand is well known as a narcotic. The presence of this compound in soils might very well cause a growth inhibition if absorbed since some narcotics in low concentration do cause a slowdown of photosynthesis and respiration (7).

Further evidence that the dry weight increase for the 5 PPM potassium penicillin treated group and the dry weight decrease for the .5 PPM procaine penicillin treated group due to factors other than inherited physiological differences is offered through a comparison of control plant data for both the potassium and procaine groups. The difference in dry weight for control plants of Ex. I and Ex. II is only 14%. It is to be remembered that these plants were planted at the same time and grown under identical light and moisture, and temperature conditions.

Attention is also called to the results observed when the control plants from Experiment VII were divided into three groups of 12 plants each before dry weight was measured. The greatest dry weight difference between these three groups was only 10 per cent. Thus, in two instances where (theoretically) identical dry weights should have been obtained between two and three groups of plants the differences were only 14 per cent and 10 per cent. It is thought after considering the above mentioned comparisons that a weight difference of over 20 per cent is due, partially at least, to either the cations potassium and procaine or to the anion penicillin derived from antibiotic treatment.

The results of Experiments IV, V, and VI show no dry weight increase over 10 per cent for treated over control, nor any dry weight decrease of over 18 per cent. Height differences, too, were slight. However, what is thought to be a significant factor is observed in that all experiments show the same general trend as to dry weight and height. The .5 or 1 PPM groups are generally of lower dry weight and height than are the controls (Tables I, II, III, V, VI). An increase in dry weight then occurs through 3, 5, and 10 PPM groups in many cases, with a leveling off or drop of dry weight and height in the 10 or 20 PPM groups (Tables I, II, III, V, VI). This appears

to the writer to be further indication that the antibiotic treatments did have some effect on the plants.

Results showing less than 20 per cent dry weight increase are thought not to be conclusive evidence for the effect of antibiotics, however, some importance may be attached to the fact that in Experiment VII, using 36 treated and 36 control plants, treated plants showed nearly the same dry weight increase as the corresponding group in Experiment V. The results of Experiment VII further strongly indicate that a concentration of 5 PPM erythromycin may be the cause for an increase in dry weight. However, even using the number of plants as in Experiment VII there still remains the possibility that a dry weight increase of only 8 per cent is likely to be due to factors other than antibiotic treatment.

The most nearly constant dry weight, wet weight and average heights are found in Experiment VI, the streptomycin sulfate treated group. This lack of significant effects on growth by the streptomycin treatments may be due to the fact that streptomycin is adsorbed by soil particles, and is practically inactivated in this manner (10). It was also found that adsorbed streptomycin is difficult to remove by base exchange procedures: ion exchange has been found to be one of the ways in which roots of higher plants absorb materials (7). It should not be inferred from the preceding statement, however, that streptomycin was not absorbed by the roots of the corn plants in Experiment VI, for it has been shown that from an aqueous solution streptomycin is absorbed by soy bean seedlings (11). If there is an effect on growth of corn by these lower concentrations of streptomycin, it would have to be considered a general growth inhibition similar to the effect of the procaine penicillin in Experiment II.

Anderson (11) has found that at concentrations of 50 to 200 units/ml. streptomycin is toxic to tomato and radish seedlings and stunts soy bean seedlings which as seeds had been immersed in a solution containing the antibiotic. The corn plants in Experiment VI were given from 140 to 5920 Mcg. of streptomycin per week, so it may very well be that if any streptomycin was absorbed inhibition of growth occurred.

In a study similar to the one under consideration, Nickell (12) has found that terramycin apparently stimulates growth and increases

germination of corn seed. However, Nickell (12) obtained only 41 per cent germination of antibiotic treated seed and 25 per cent germination of control seed. It seems that seeds which should be expected to give accurate results would have given a much higher percentage of germination in both cases. It has been shown that terramycin is inactivated, it too may be adsorbed by soil particles (13). The growth increase of the treated group over controls in Nickell's (12) study was 27.5 per cent on a dry weight basis, and 25 per cent on an average height basis. The conditions under which Nickell (12) grew his corn plants (in two greenhouse flats) did not rule out root competition. Thus the significance of results in Nickell's study is doubtful just as it is in the present study. Of course, it may be argued that in Nickell's study the control plants being fewer and probably planted farther apart had every advantage to outstrip the treated plants in weight because the controls would have more room for root growth and increased light conditions, (Nickell used 12 control and 20 treated plants). It is suspected that after four weeks of growth twenty corn plants averaging over 17 inches in height would be crowded for space if grown in a standard size greenhouse flat, the dimensions of which are about 18 by 24 inches. It is very possible, therefore, that growing in individual pots corn plants treated with terramycin may show more than 27.5 per cent dry weight increase. Both Nickell's and the present results should be accepted with reservation until further experiments with terramycin are performed.

SUMMARY

1. This study deals with effects of 5 antibiotics on growth of young corn plants.
2. Indications are that a 5 PPM solution of potassium penicillin increases growth of young corn plants which are watered with 25 ml. of the solution per plant four times a week for a period of four weeks.
3. Indications are that a .5 PPM solution of procaine penicillin inhibits growth of young corn plants when treated with 25 ml. of the antibiotic solution per plant four times a week for four weeks.
4. If the growth increases and decreases were due to potassium and procaine penicillin respectively the possibility exists that these effects may have been due to the potassium and procaine rather than the penicillin.

5. Effects on growth of corn plants of the antibiotics bacitracin, erythromycin and streptomycin are thought to be slight.

6. Tests sensitive to 4 Mcg./ml. for presence of erythromycin in water extracts of treated plants and control plants were negative.

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TABLE I

Height and weight of treated and control plants from Experiment I
(Potassium Penicillin)

Concentration PPM.	Height (Cm.)			Weight (Gms.)		% of dry weight of control
	Avg.	Median	Mode	Wet	Dry	
Control	25.3	26	21	49	4.3	100
.5	22.3	20	21	44.5	4.2	98
1	21.2	22	22.5	50.6	5.4	126
3	22.5	23.5	24	45.5	4.7	110
5	24.8	25	22	55.2	6.0	140
10	24.8	25	22	45.8	4.6	108

TABLE II

Height and weight of treated and control plants from Experiment II
(Procaine Penicillin)

Concentration PPM.	Height (Cm.)			Weight (Gms.)		% of dry weight of control
	Avg.	Median	Mode	Wet	Dry	
Control	23.4	22	22	45.6	4.9	100
.5	19.4	18	18	37.2	3.9	80
1	20.7	20	21	41.7	4.5	92
3	21.1	20.5	22	47.6	5.4	110
5	22.2	22	24.5	42.8	4.3	88
10	23.2	24	21	44.3	4.9	100

TABLE III

Height and weight of treated and control plants from Experiment IV
(Bacitracin)

Concentration PPM.	Height (Cm.)			Weight (Gms.)		
	Avg.	Median	Mode	Wet	Dry	% of dry weight of control
Control	20.9	18	20	28.1	3.1	100
.5	22.4	20	30	31.2	2.6	84
1	19.0	20	20	30.9	2.9	94
3	20.2	19	22	27.2	2.6	84
5	23.1	23	25	38.2	3.4	110
10	22.7	20	20	28.8	2.9	94

TABLE IV

Height and weight of treated and control plants from Experiment III
(Potassium Penicillin)

Concentration PPM.	Height (Cm.)			Weight (Gms.)		
	Avg.	Median	Mode	Wet	Dry	% of dry weight of control
Control	22.5	22	24	68.5	6.1	100
5	20	19	19	63.6	6.7	110

TABLE V

Height and weight of treated and control plants from Experiment V
(Erythromycin)

Concentration PPM.	Height (Cm.)			Weight (Gms.)		
	Avg.	Median	Mode	Wet	Dry	% of dry weight of control
Control	31.0	31	33	54.1	6.8	100
1	30	30	30	51.3	5.6	82
3	30.4	30	31	54.9	6.6	97
5	31.4	31	35	68.1	7.5	110
10	32.7	32	35	56.3	6.1	90
20	32.4	32	35	61.4	7.1	104

TABLE VI

Height and weight of treated and control plants from Experiment VI
(Streptomycin)

Concentration PPM.	Height (Cm.)			Weight (Gms.)		% of dry weight of control
	Avg.	Median	Mode	Wet	Dry	
Control	30.3	28	28.5	66.2	7.7	100
1	29.7	29	29	57.2	7.1	92
3	28.0	28	30	58.7	7.4	95
5	28.5	29	30	53.2	7.3	95
10	27.8	29	30	63.5	7.8	101
20	29.9	29	32	52.4	6.9	90

TABLE VII

Height and weight of treated and control plants from Experiment VII
(erythromycin)

Concentration PPM.	Height (Cm.)			Weight (Gms.)		% of dry weight of control
	Avg.	Median	Mode	Wet	Dry	
Control	27.0	28	29	118.7	13.0	100
5 PPM	27.6	28	30	117.1	14.0	108

TABLE VIII

Showing dry weight % above or below control dry weight for various
concentrations—for comparison

Antibiotic	Concentration (PPM)					
	.5	1	3	5	10	20
K Penicillin	98%	126%	110%	140%	108%	
Procaine	80	92	110	88	100	
Bacitracin	84	94	84	110	94	
Erythromycin		82	97	110	90	104%
Streptomycin		92	95	95	101	90

THE USE OF ALGAL CULTURES IN EXPERIMENTS CONCERNED WITH WATER SUPPLY PROBLEMS

*By C. MERVIN PALMER AND THOMAS E. MALONEY**

Rapid and routine methods for isolating and culturing algae are essential for laboratory studies of those algae which create problems in water supplies and for the development of methods for their control. Just as the bacteriologist must isolate the bacteria in order to study their actions under various conditions, so too, the applied phyco-
logist must now follow essentially the same procedure with the algae. Matheson (1952) has emphasized this need in his recent report to the 1952 Congress of the International Water Supply Association.

Carefully controlled experiments involving algae can be accomplished only when pure algal cultures, free of all other organisms, are available. In general it is not as easy to obtain a pure culture of algae as it is to obtain a pure culture of bacteria because it is difficult to separate contaminants from algal cells and the algal cultures grow slowly and must be kept longer. Once such a culture is obtained a number of pertinent investigations can be made such as screening tests for algicides, determining the effect on algae of changes in their physical and chemical environment, the determination of growth characteristics in standard media, determination of growth rates, the selection of indicator algae in polluted water, and experiments involving the testing of products of algal growth for tastes, odors, and toxicity.

The initial step in isolating algae to obtain pure cultures frequently involves dilution and plating out on a semi-solid medium. A number of diatoms, green and blue-green algae will develop as colonies on liquefiable solid media. These colonies are then transferred to sterile media. Since contaminants are difficult to separate from algal cells, one or more of the following additional methods may be required to obtain pure cultures: selective media, exposure to ultra-violet, utilization of antibiotics (Pappas and Hoffman, 1952), centri-

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fuging, repetition of plating out procedures, and single thallus isolation by means of a micro-pipette. The standard thioglycollate and mycophil broths are recommended in testing for contamination by molds and bacteria. In addition to these organisms, the green alga *Chlorella*, some of the amoeboid protozoa, and yeasts are among the other contaminants which almost invariably have to be eliminated. Several of the flagellate algae generally considered as taste and odor producers, do not form recognizable colonies on semi-solid media. These must be isolated by the more tedious method of the micro-pipette.

In the culturing of various genera and species of algae, it is desirable to select a few general purpose media, each of which permits the active growth of a number of types of algae. This procedure makes possible a direct comparison of the several algae in a common type of culture medium. Gerloff's modification of Chu's #10 medium (Gerloff, Fitzgerald, and Skoog, 1950; Chu, 1942) has been found to be excellent for many blue-green algae and, in addition, for several green algae and a few diatoms. It is a synthetic medium, contains carbonate in addition to the usual nutrients and has a relatively high pH, approximating 8.5.

A low pH medium may be required for certain of the phytoflagellates. A formula furnished by Dr. L. Provasoli of the Haskins Laboratory, which calls for the use of peat extract as one of the ingredients is now being tested. The medium has a pH of 5 and has been used successfully by Dr. Provasoli for the culture of *Synura*, *Pandorina*, and *Peridinium*.

A third medium should be one approximating pH 7 which would be suitable for isolating and culturing some of the many species of diatoms, desmids, golden brown and filamentous green algae which seldom are found growing in the low and high pH media already being used. Rodhe (1948) has developed a medium which comes close to meeting this need in water supply research. He reported his medium VIII to be "very suitable for unlimited cultivation of about forty species and forms belonging to Chlorococcales, Volvocales, Conjugatae, Heterokontae, and diatoms."

The incubation room for algal cultures at the Environmental Health Center has been described in a previous paper (Palmer, 1952).

This room which has continuous illumination, with fluorescent tubes at an intensity of 140 foot candles, and is provided with an air conditioner to hold the temperature at 22° C, has been found very satisfactory for the experiments conducted to date. New cultures inoculated with one part of an active liquid culture to twenty-five parts of sterile medium, will generally develop visible growth within three days in this culture room. In many of the cultures growth often continues for one to four weeks.

When more adequate provisions become available in the new laboratory of the Environmental Health Center, it is planned to test the growth of algal cultures under various combinations of light intensities and temperatures. It is quite probable that the optimum conditions may be found to differ from those now in use.

For simple screening tests, a very satisfactory receptacle for individual cultures is the 25 ml Erlenmeyer flask. Its small size is economical of space and its flat bottom furnishes a surface over which the algae may grow. Tests are now being made with the still smaller 10 ml flask which would be even more efficient in the use of space.

For the continuous growth of algae in pure cultures, a separatory funnel has been found convenient. A special ground glass stopper can be made for the top to provide openings for entrance and exit of gas and for the addition of liquid nutrients. The opening at the bottom permits easy drainage of any or all of the medium in which the algae have been growing. By placing a fluffy mass of sterile glass wool in the funnel, most of the algae will attach themselves to the wool rather than to the surface of the funnel. This permits the extraction of the liquid medium from the funnel without disturbing the mass of algal growth. Since the glass wool tends to float, gas can be bubbled through the entire algal growth. This would not be possible if the algae were permitted to develop on the surface of the funnel.

Rejuvenation of old cultures of algae which have turned brown to yellow with age can often be accomplished by the addition of supplementary nitrate solution. Some algae respond within a period of a few hours while others may require a week or more. However, it may be more satisfactory to store stock cultures in a semi-dormant state in a refrigerator than to depend on the rejuvenation of aged cul-

tures. The storage refrigerator used for this purpose at the Environmental Health Center is furnished with fluorescent light tubes and it can be used also as an incubator for some of the psychrophilic algae.

The above techniques have been used to conduct under controlled environmental conditions numerous serial dilution tests with potential algicides on a considerable number of algae. Other experiments are being conducted to determine the effect of particular environmental changes on algal growth. Although much remains to be done in the development of techniques for the routine culturing of algae it is now planned to undertake direct laboratory studies on the production of tastes and odors by algae. While many procedures for the culturing of particular kinds of algae have been described in the literature, what is now required in the Biology Laboratory of the Environmental Health Center is a procedure for comparative research with many kinds of algae under uniform conditions. At the present time, more than fifty uni-algal cultures representing approximately thirty-five species and varieties are being used and others are being prepared for addition to this list. Forms under study at present are those which are most readily cultivated and include *Chlorella*, *Scenedesmus*, *Chlamydomonas*, *Ankistrodesmus*, *Oocystis*, *Phormidium*, *Calothrix*, *Achnanthes*, and *Nitzschia*. Modification and improvement of techniques are required to allow the rapid isolation and continuous cultivation of many other algae of importance in the provision of satisfactory water supplies.

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THE PHYTOPLANKTON OF LAKE WAWASEE, KOSCIUSKO COUNTY, INDIANA

By WILLIAM A. DAILY AND EVERETT E. MINER

Lake Wawasee located at Syracuse, Indiana, is the largest body of water in the state. It has an area of 2,618 acres, a maximum depth of 68 feet and a shore line of approximately 22 miles.

To our knowledge, the only paper published in which phytoplankters of Lake Wawasee are mentioned appeared in 1896 (C. H. Eigenmann, Proc. Ind. Acad. Sci. p. 240, 1895). Those were *Ceratium hirundinella*, *Rivularia* and "various forms of *Palmella*."

In 1950 from July 23 to July 30 and on April 28, 1951, W. A. and F. K. Daily made a total of 15 plankton net collections from different stations on the lake. Everett E. Miner of Syracuse, Indiana, then made 26 weekly (or nearly so) net hauls from the pier of the Eli Lilly estate during the period May 1, to October 30, 1951.

Thirty-five genera, 47 species and 3 varieties representing 6 classes of the algae are recorded. All of the above collections are to be found on file in the herbaria of Butler University and the Chicago Natural History Museum.

All of the photomicrographs were made from herbarium specimen mica slips mounted in water. At the magnification used, 1 millimeter equals 2.0 microns.

MYXOPHYCEAE

Anacystis cyanea (Kütz.) Drouet and Daily. Pl. 1, Fig. 9.

Anacystis limnetica (Lemm.) Drouet and Daily f. *limnetica*. Pl. 1, Fig. 6.

Anacystis dimidiata (Kütz.) Drouet and Daily. Pl. 1, Figs. 4 & 5.

Merismopedia tranquilla (Ehrenb.) Trevis. Pl. 1, Fig. 7.

Merismopedia thermalis Kütz. Pl. 1, Fig. 8.

Gomphosphaeria Wichurae (Hilse) Drouet and Daily. Pl. 1, Fig. 2.

Gomphosphaeria lacustris Chod. Pl. 1, Fig. 1.

Gomphosphaeria aponina Kütz. Pl. 1, Fig. 3.

Anabaena flos-aquae (Lyngb.) Breb. ex B. and F. Pl. 2, Fig. 1.

- Anabaena circinalis* (Kütz.) Rabenh. ex B. and F. Pl. 2, Fig. 5.
Aphanizomenon flos-aquae (L.) Ralfs ex B. and F. Pl. 2, Fig. 2.
Gloeotrichia echinulata (J. E. Smith) Richter ex B. and F. Pl. 3,
 Fig. 3.
Oscillatoria rubescens Gom. Pl. 2, Fig. 4.
Lyngbya Birgei G. M. Smith. Pl. 2, Fig. 3.

CHLOROPHYCEAE

- Pandorina morum* Bory.
Eudorina elegans Ehrenb. Pl. 3, Fig. 1.
Sphaerocystis Schroeteri Chod. Pl. 5, Fig. 6.
Dimorphococcus lunatus A. Br. Pl. 4, Fig. 2.
Pediastrum Boryanum (Turp.) Menegh. Pl. 4, Fig. 5.
Pediastrum tetras (Ehrenb.) Ralfs. Pl. 5, Fig. 4.
Coelastrum microporum Näg. Pl. 4, Fig. 4.
Coelastrum reticulatum (Dang.) Senn.
Kirchneriella lunaris (Kirchner) Möbius
Ankistrodesmus falcatus (Corda) Ralfs.
Crucigenia rectangularis (A. Br.) Gay. Pl. 4, Fig. 1.
Scenedesmus bijuga (Turp.) Lagerh.
Scenedesmus quadricauda (Turp.) Breb. Pl. 4, Fig. 3.
Scenedesmus arcuatus Lemm. Pl. 5, Fig. 2.
Staurostrum sp.

BACILLARIOPHYCEAE

- Melosira granulata* (Ehrenb.) Ralfs. Pl. 6, Fig. 6.
 Identified by Mr. J. H. Wallace.
Melosira granulata var. *angustissima* Müller.
Melosira italica (Ehrenb.) Kütz.
 Identified by Mr. J. H. Wallace.
Cyclotella Meneghiniana Kütz. Pl. 5, Fig. 3.
Cyclotella compta (Ehrenb.) Kütz:
 Identified by Mr. J. H. Wallace and Dr. M. H. Hohn.
Stephanodiscus niagarae Ehrenb. Pl. 6, Fig. 2.
Rhizosolenia eriensis H. L. Smith. Pl. 6, Fig. 4.
Tabellaria fenestrata (Lyngb.) Kütz. Pl. 5, Fig. 7.
Tabellaria flocculosa (Roth) Kütz.
Fragilaria crotonensis Kitton. Pl. 6, Fig. 3.
Fragilaria virescens Ralfs. Pl. 5, Fig. 5.

Asterionella formosa Hass. Pl. 5, Fig. 1.

Synedra ulna var. *Chascana* (Thomas) Boyer. Pl. 6, Fig. 5.

Identified by Mr. J. H. Wallace and Dr. M. H. Hohn.

Synedra ulna var. *danica* (Kütz.) Grun.

Identified by Mr. J. H. Wallace and Dr. M. H. Hohn.

Amphiprora ornata Bailey.

Cymatopleura solea (Breb.) W. Smith. Pl. 6, Fig. 7.

Surirella ovalis Breb.

DINOPHYCEAE

Gonyaulax palustre Lemm. Pl. 4, Fig. 1, in lower right hand quadrant.

Ceratium hirundinella (O.F.M.) Schrank. Pl. 6, Fig. 1.

XANTHOPHYCEAE

Botryococcus Braunii Kütz. Pl. 3, Fig. 2.

CHRYSOPHYCEAE

Mallomonas alpina Pascher and Ruttner.

Dinobryon divergens Imhof. Pl. 4, Fig. 6.

We wish to thank Mrs. Fay K. Daily for aid in preparation of this paper, Mr. John H. Wallace and Dr. Matthew H. Hohn for identifying several of the diatoms and Dr. Francis Drouet for suggestions.

Technical advice given by Mr. E. B. Byfield and Mr. O. G. Klein of the Printing Department of Eli Lilly and Company is gratefully acknowledged.

The Herbarium
Butler University

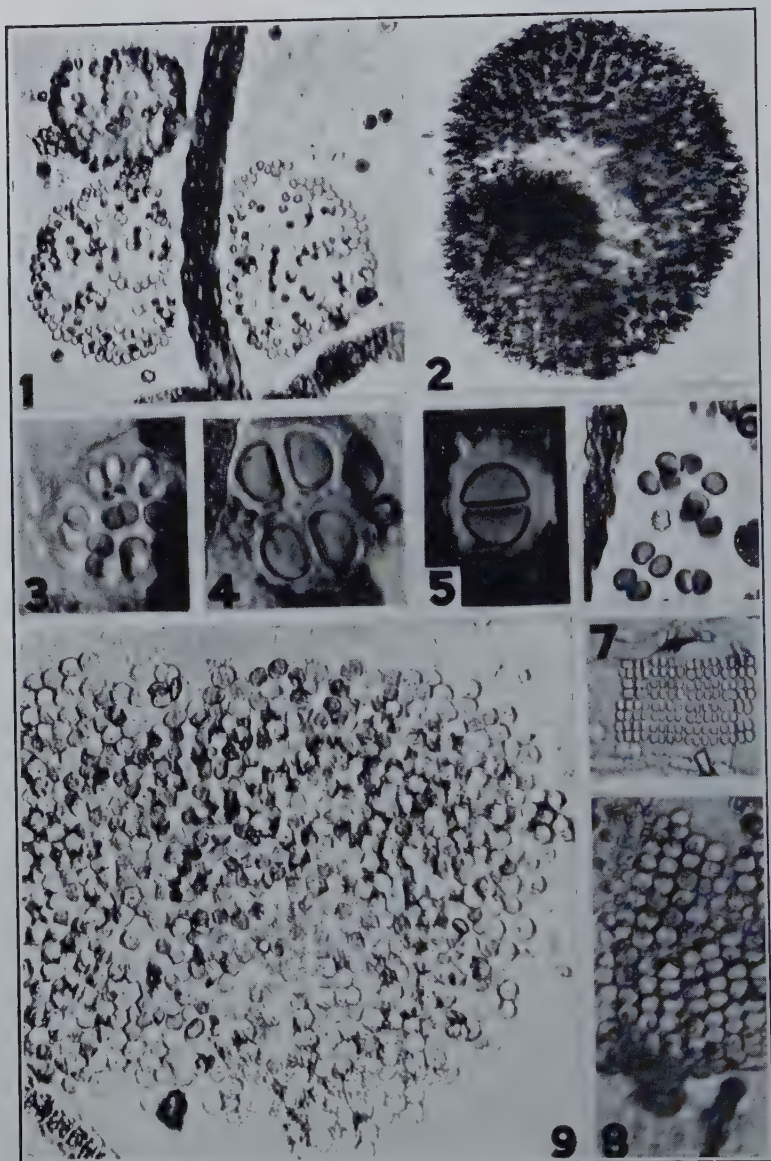


Plate 1. Fig. 1. *Gomphosphaeria lacustris* Chod. Fig. 2. *Gomphosphaeria Wichurae* (Hilse) Dr. & Daily. Fig. 3. *Gomphosphaeria aponina* Kütz. Figs. 4 & 5. *Anacystis dimidiata* (Kütz.) Dr. & Daily. Fig. 6. *Anacystis limnetica* (Lemm.) Dr. & Daily f. *limnetica*. Fig. 7. *Merismopedia tranquilla* (Ehrenb.) Trevis. Fig. 8. *Merismopedia thermalis* Kütz. Fig. 9. *Anacystis cyanea* (Kütz.) Dr. & Daily.



Plate 2. Fig. 1. *Anabaena flos-aquae* (Lyngb.) Breb. ex B. & F. Fig. 2. *Aphanizomenon flos-aquae* (L.) Ralfs ex B. & F. Fig. 3. *Lyngbya Birgei* G. M. Smith. Fig. 4. *Oscillatoria rubescens* D. C. ex Gom. Fig. 5. *Anabaena circinalis* (Kütz.) Rabenh. ex B. & F.

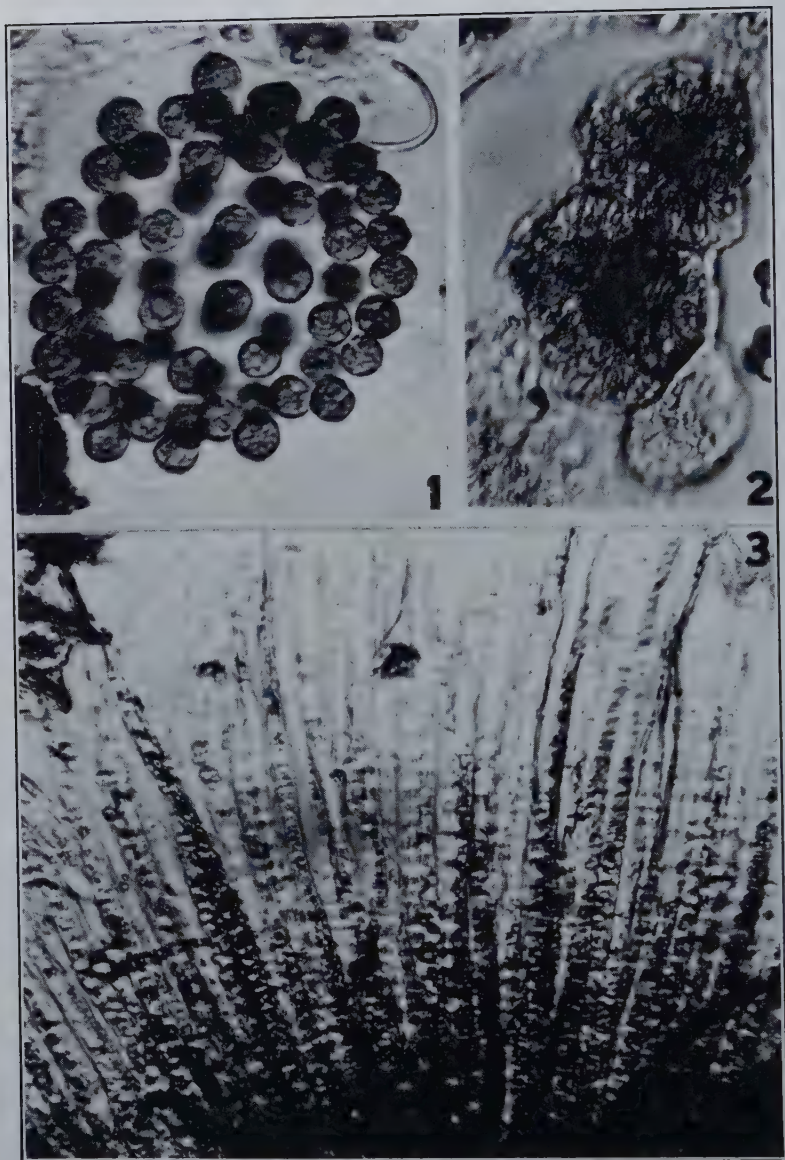


Plate 3. Fig. 1. *Eudorina elegans* Ehrenb. Fig. 2. *Botryococcus Braunii* Kütz. Fig. 3. *Gloeotrichia echinulata* (J. E. Smith) P. Richt. ex B. & F.

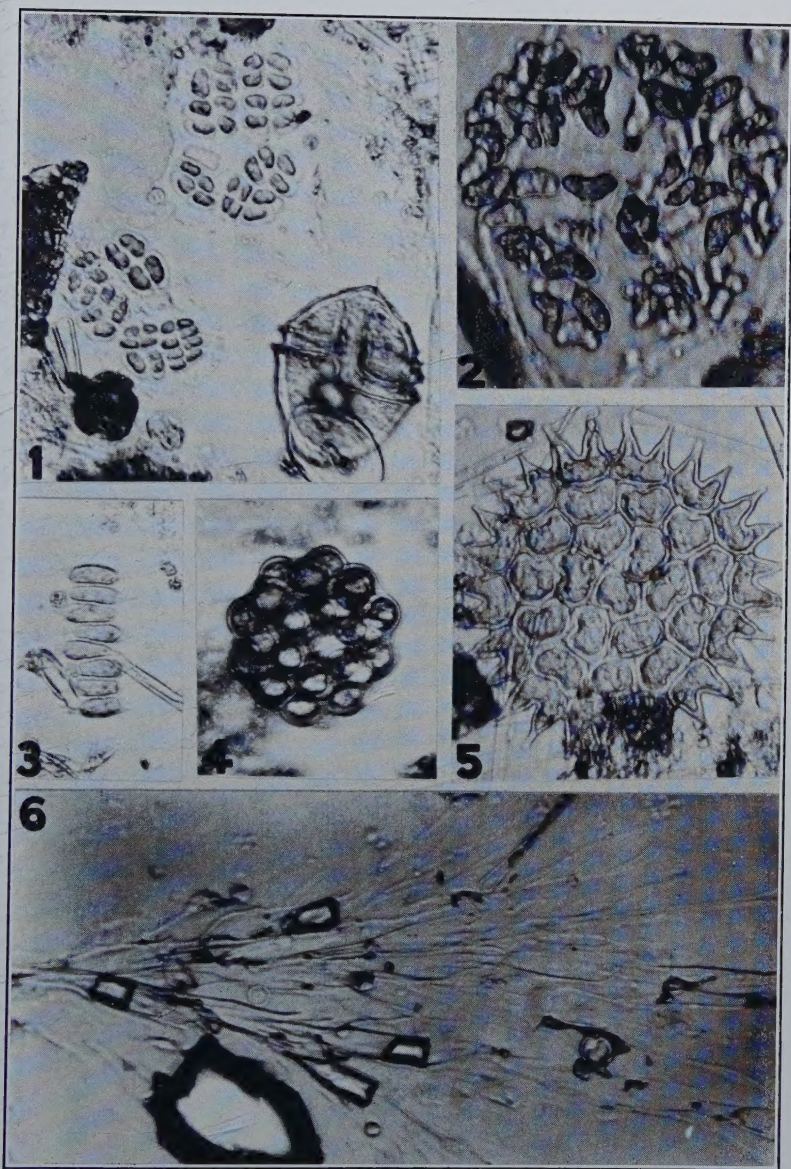


Plate 4. Fig. 1. *Crucigenia rectangularis* (Näg.) Gay. In lower right quadrant, *Gonyaulax palustre* Lemm. Fig. 2. *Dimorphococcus lunatus* A. Br. Fig. 3. *Scenedesmus quadricauda* (Turp.) Breb. Fig. 4. *Coelastrum microporum* Næg. Fig. 5. *Pediastrum Boryanum* (Turp.) Menegh. Fig. 6. *Dinobryon divergens* Imhof.

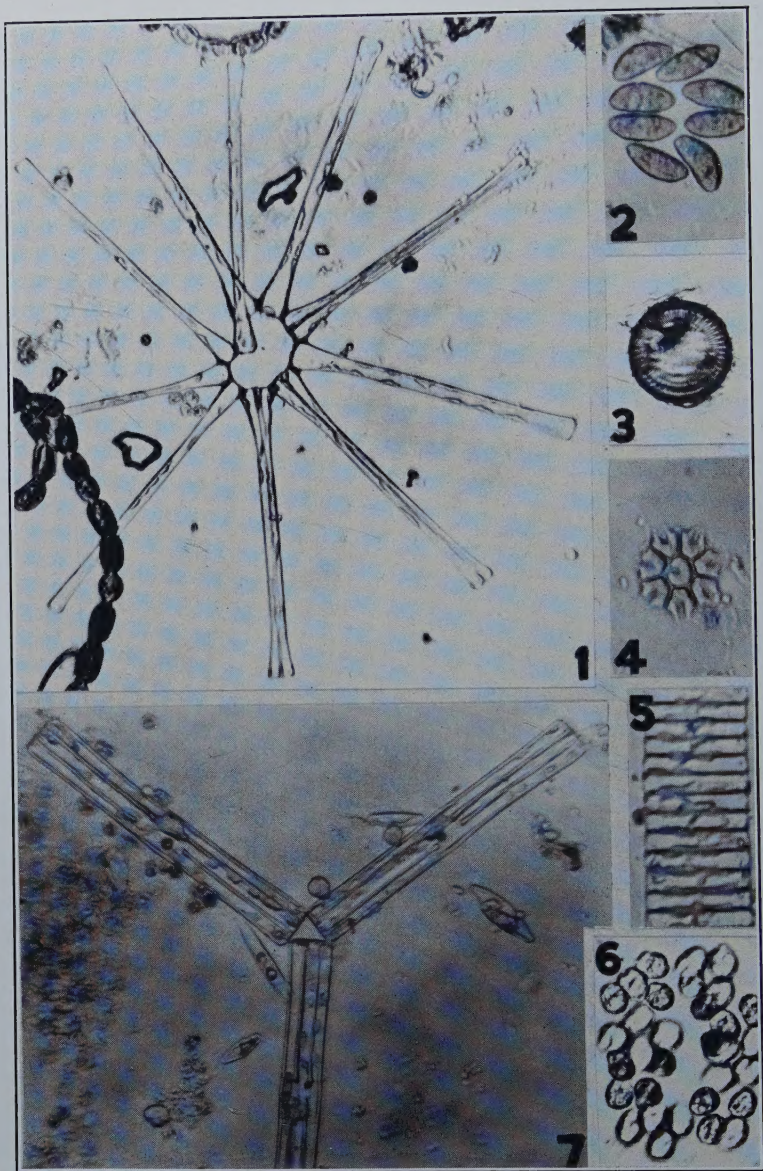


Plate 5. Fig. 1. *Asterionella formosa* Hass. Fig. 2. *Scenedesmus arcuatus* Lemm. Fig. 3. *Cyclotella Meneghiniana* Kütz. Fig. 4. *Pediatrurn tetras* (Ehrenb.) Ralfs. Fig. 5. *Fragilaria virescens* Ralfs. Fig. 6. *Sphaerocystis Schroeteri* Chodat. Fig. 7. *Tabellaria fenestrata* (Lyngb.) Kütz.

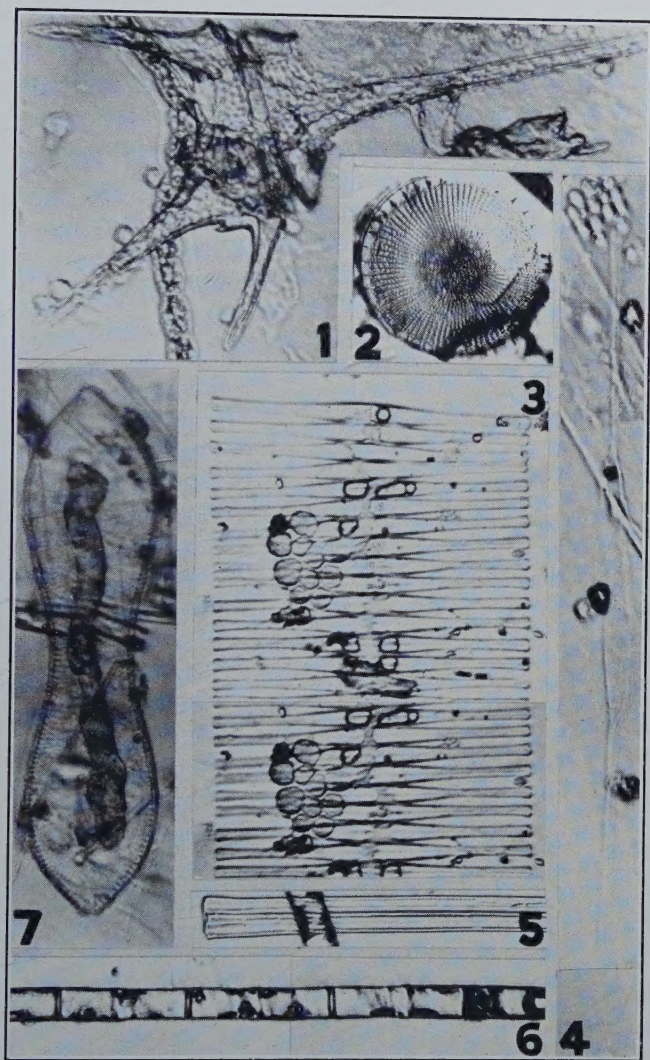


Plate 6. Fig. 1. *Ceratium Hirundinella* (O.F.M.) Schrank. Fig. 2. *Stephanodiscus niagare* Ehrenb. Fig. 3. *Fragilaria crotonensis* Kit. Fig. 4. *Rhizosolenia eriensis* H. L. Smith. Fig. 5. *Synedra ulna* var. *Chaseana* (Thomas) Boyer. Fig. 6. *Melosira granulata* Ehrenb. Fig. 7. *Cymatopleura solea* (Breb.) W. Smith.

